Stow Residential Energy Use and Greenhouse Gas Emissions

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Introduction

This paper presents a look at residential energy use and greenhouse gas emissions in Stow. The paper was produced by the Stow Energy Group using data from a variety of sources including our electric utility, Hudson Light and Power and information from town offices. For Stow residential energy use – energy used in the home and for private transportation – represents the majority of the town's energy consumption. Municipal and commercial energy use, though significant, is about a third of the total energy used in our town.

To provide context for our energy use, comparisons to other regions in the U.S. and the world are presented. An overview of climate change is included along with the consensus view of the targeted reductions in greenhouse gas needed to avoid the worst consequences of climate change. These targets are put in a local context and we look at what is needed in Stow to meet greenhouse gas reduction targets for 10 years from now and mid-century. The paper includes, what we believe is helpful information for town residents to understand and consider. Both when making their own household energy choices, and in facing our global energy challenges.

Stow Household Data

Source data for Stow households was obtained from the 2000 census, the Stow Board of Assessors, and information provided by local energy providers – Hudson Light & Power, Dunn Oil, and Nstar.

Per the 2000 census, Stow had a population of 5,902 living in 2,082 households. Of those 2,082 households, 1,933 lived in single unit detached homes. Ten years later, in 2010, our population has increased by about 600 and the number of single-family homes recorded by the town assessor is 2047. The average size of a single-family home is 2,347 square feet.

In 2000 average household size was 2.82 individuals and there were 2.1 vehicles per household. Transportation's contribution to residential energy will be analyzed later in the paper.

As will be described, the major variable in home energy use is the fuel used for heating. In 2000, the breakdown was:

Heating Fuel	Number of Households	Percent
Natural gas	433	20.8%
Bottled gas	38	1.8%
Electricity	182	8.7%
Fuel oil	1,343	64.5%
Wood	66	3.2%
Other fuel	20	1.0%

From data provided by Hudson Light & Power, 189 of their residential customers in Stow in 2009 were 'all electric' (Service "F") which is close to the 182 households who reported using electricity for heating in the 2000 census.

Overview of Stow Residential Energy Use

Considered here is energy used directly in the home and for residential transportation.. Not considered are a number of other direct and indirect uses of energy including:

- The energy required to produce our food and transport it to local retailers.
- The energy used to manufacture the products we purchase.
- The energy used for air travel
- The greenhouse gas emissions from our trash

Nonetheless, a look at our direct home and transportation energy use is a valuable metric and one that enables comparisons to other communities and countries.

Also not considered here is municipal and commercial energy use in Stow. The data available indicates residential energy use comprises the bulk, between two thirds and three quarters, of overall town energy use. This data includes:

- Energy audits of municipal buildings. For example, it was found the Town Building consumed 954 Mbtu (natural gas and electricity) in 2008. This is about equivalent to the energy used by fourteen homes in Stow.
- Stow electric use in 2009 was 63% residential, 34% commercial, and 3% municipal.
- Town wide energy audits conducted by other towns with similar 'profiles' to Stow found the bulk of their energy use was residential.

Primary Residential Energy Fuels

This is a brief overview of the primary residential fuels used in Stow. Additional detail for electricity is contained in Appendix A. The table below lists the primary fuels, fuel cost, equivalent energy in Mbtu (for purposes of comparison), and C02 emissions per unit of energy.

Fuel	Cost (2009 average)	Cost per Mbtu (2009 average)	CO2 Emission (lbs per Mbtu)
Natural Gas	$1.80 per them	$18.00	111
Fuel Oil	$2.80 per gallon	$18.70	161
Gasoline	$2.50 per gallon	$16.66	156
Electricity (general)			0 to 685
Electricity (U.S average)			443
Electricity (Stow)	$0.135 per KWh	$39.55	143

Characteristics of Residential Energy Fuels

As shown in the table, natural gas has significantly lower CO2 emission per unit of energy than fuel oil or gasoline. Three rows are included for electricity; "Electricity (general)", "Electricity (U.S. average)", and "Electricity (Stow)". This is to illustrate the dramatic variation in CO2 emission from electric generation.

Natural gas, fuel oil, and gasoline are fossil fuels burned directly to produce energy (e.g. heat, hot water, gasoline engine) for residential use. These fuels are called *primary* source fuels when used directly as a source of energy. However, nearly all electricity is generated at remote power plants and delivered to the home over the electric transmission grid. Fuel used to generate electricity this way is a *secondary* energy source.

The CO2 emissions from electric power generation depend on the mix of fuels used to generate the electricity, the efficiency of electric power generation, and power losses in the transmission lines. When fossil fuels (coal, oil, natural gas) are used to generate electricity, the combination of the efficiency of the generation and transmission losses result in an increase of CO2 emission, per unit of generated energy, from that of the fuel alone by over a factor of three (see Appendix A). This results in a worst case of 685 pounds of CO2 per Mbtu of delivered electricity when coal is burned to generate electricity (205 pounds of CO2 are emitted per Mbtu of coal burned). The best case of no CO2 emission occurs when no fossil fuels are used in the generation of electricity (e.g. hydroelectric, nuclear, wind, solar). The U.S. average for electric generation is currently about 443 lbs of CO2 per Mbtu. In Stow, we enjoy very clean electricity with well under half the national average of CO2 emissions. It is vitally important to keep in mind the dramatic variability in CO2 emissions from electric generation both today and, even more significantly, going forward. Today electric generation accounts for about 42% of CO2 emissions in the U.S. In the future, electricity will be an even more important source of energy – as some of the current sources of energy are replaced by electricity – for example plug-in hybrids and electric cars. For all uses of electricity, it is only as clean as the fuel used to generate it.

Electricity in Stow

Electric service in Stow is provided by Hudson Light & Power (HL&P), a municipal utility that also serves the town of Hudson and some homes in Boxboro, Bolton, Berlin, and Marlboro. HL&P is one of 41 municipal utilities in Massachusetts. The other form of electric service in the state is Investor Owned Utilities (IOUs). Currently, 87% of customers in the state are serviced by IOUs and 13% by municipal utilities.

Overall, municipal utilities provide highly reliable service and, in general, at lower cost to their customers than IOUs. HL&P is no exception. Our electric rates are very competitive and service is excellent. On the other hand, unlike IOUs, municipal utilities are exempt from implementing many of the state's energy policies. These include energy efficiency programs, renewable energy standards, and a variety of initiatives under the state's Green Communities Act. While many municipal utilities, including HL&P, voluntarily adopt various aspects of the state's energy policies, many have not.

HL&P is doing an excellent job providing Stow with clean electricity. Their monthly customer newsline includes a "Green Corner". As of the end of August 2010, over 71% of electricity was 'greenhouse gas free'. The breakdown of fuel sources is contained in Appendix A

Natural Gas in Stow

Nstar provides limited natural gas service in Stow. Primarily, homes along route 117 have the option to use natural gas. There are no known plans to expand natural gas service in the near term.

Fuel oil and gasoline in Stow

Nearly two thirds of Stow homes heat with fuel oil. The Northeast is the only region of the country where a significant number of homes use fuel oil. Fuel oil is delivered by truck and there are a number of local fuel oil providers servicing Stow.

Gasoline is available in Stow as in the rest of the country. The major variation is cost which is subject to both federal and state taxes. Massachusetts ranks below the national average in gasoline tax ($0.419 per gallon in MA compared to the national average of $0.481).

Stow Residential Energy Use

Total annual energy use and CO_2 emissions for Stow homes and residential transportation is shown in the table below. Energy use is converted to Mbtu (Million btu) as a common unit regardless of fuel. CO_2 emissions are shown in pounds.

For household energy use, only the primary energy sources – natural gas, fuel oil, and electricity are considered. Census data indicates the household energy contribution from other fuel sources, such as bottled gas and wood, is relatively small.

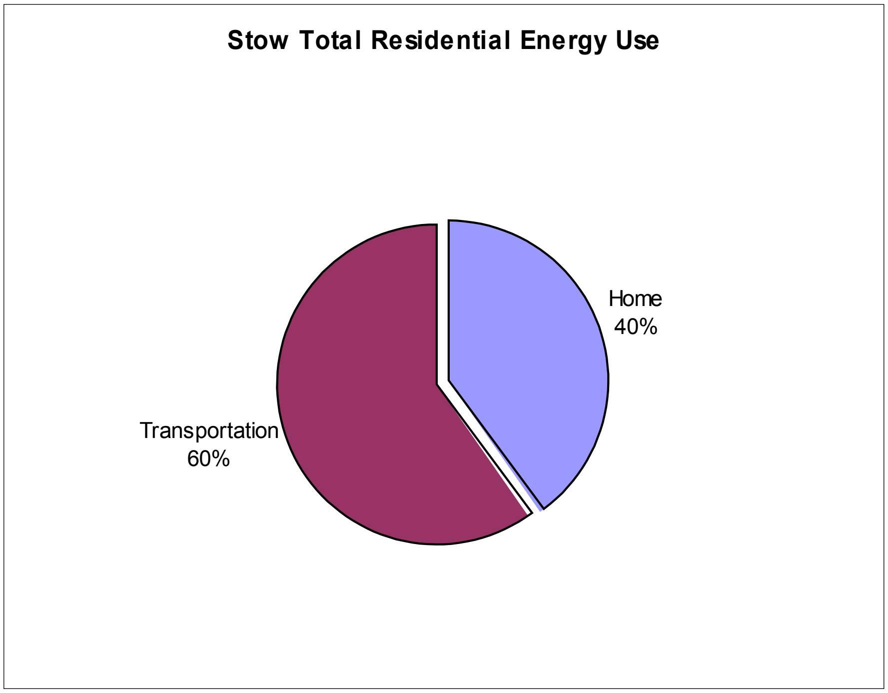
For transportation energy use, only gasoline used by private vehicles is included. Census data indicates the contribution from public transportation is small.

Detailed data for these residential energy sources is included in the Appendix B.

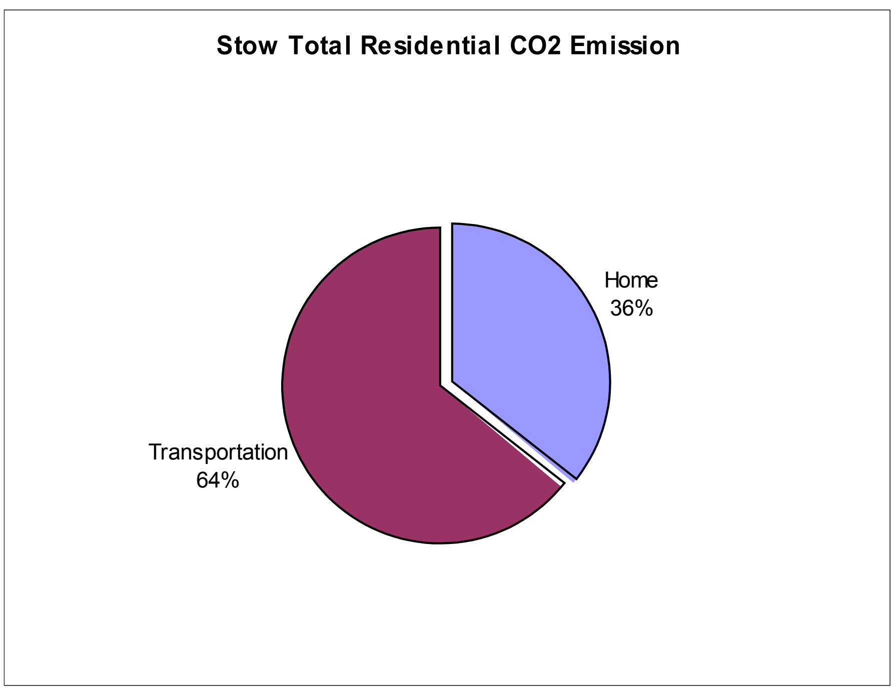
	Fuel	Total Fuel	Total Energy (Mbtu)	Total CO2 Emissions (lbs)
Household Energy Use	Natural Gas	521,883 therms	52,136	5,787,051
	Fuel Oil	1,069,344 gal	148,125	23,107,567
	Electricity	27,720,843 kwh	94,611	13,434,796
	Household Total		294,872	42,329,414
Transportation Energy Use	Gasoline	3,812,658 gal	438,456	74,575,600
Total Residential Energy Use			733,328	116,905,014

2010 Stow Residential Energy Use Summary

The two charts below illustrate this data as a percentage of total energy use and total CO_2 emissions broken down between home and transportation energy use.



Stow Total Residential Energy Use



Stow Total Residential CO2 Emissions

Stow Residential Transportation

Per the 2000 census, the vast majority of Stow commuters use private vehicles to get to and from work. Of the 3,112 residents employed in 2000, their method of commuting was the following:

Method of Travel	Number	Percent
Drove alone	2,621	84.2
Carpooled	142	4.6
Public transportation	110	3.5
Walked	36	1.2
Other means	23	0.7
Worked at home	180	5.8
Mean travel time to work	31 minutes	

Scott Peterson, a manager in the Central Transportation Planning Group of the Boston Region Metropolitan Planning Organization, generated an estimate of residential vehicle use in Stow based on survey data and projected to the baseline year 2007. Details can be found in Appendix C.

Annual Miles Driven by Passenger Vehicles	Annual fuel used (gallons)	Annual Energy Used (Mbtu)	Annual CO2 Emissions from Passenger Vehicles (lbs)	Average Daily Vehicle Miles per Household
60,894,000	3,812,658	438,456	74,575,600	85.8

Summary Stow Residential Vehicle Use

The travel data estimate includes only vehicle travel by Stow residents, not travel through Stow by residents of other towns. The following table shows the percent of miles driven as a function of the purpose of the trip. Note work commuting accounts for 24% of miles driven and trips not starting or ending at home ("non-home based") represent 19% of miles traveled.

Municipality	Home Based Work Trips	Home Based Personel Business	Home Based Social Recreation	Home Based School	Home Based Pick-up and Dropp-offs	Non-Home Based Work	Non-Home Based Other	Total
Stow	24%	26%	19%	6%	5%	9%	10%	100%
Eastern MA Average	18%	25%	17%	7%	4%	15%	13%	100%

Vehicle Miles Traveled by Trip Purpose

Stow Home Energy Use

The primary energy sources used in the home are electricity, fuel oil, and natural gas.

All homes in Stow have electric service provided by Hudson Light & Power (HL&P), a municipal utility that also serves the town of Hudson and some homes in Boxboro, Bolton, Berlin, and Marlboro. Almost two thirds of the electric use in Stow is residential. HL&P provides three residential electric services depending on whether electricity is used for hot water, both hot water and heating, or neither hot water nor heating (slightly different rates apply depending on the service). The table below shows total and household average electric use in Stow in 2009.

Service	Number of Customers	kWh	KWh/customer/year
Residential	1,974	17,278,243	8,753
Elec Hot Water Heater	578	7,015,355	12,137
All-Electric	189	3,427,245	18,134

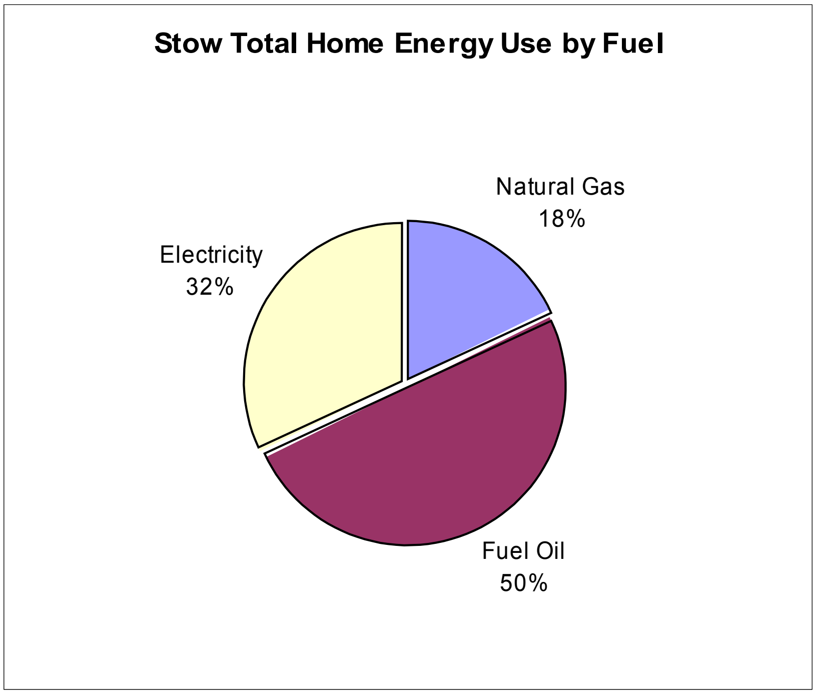
Stow Residential Electric Use (2009)

The table below shows town-wide home energy consumption and CO_2 emissions for these energy sources.

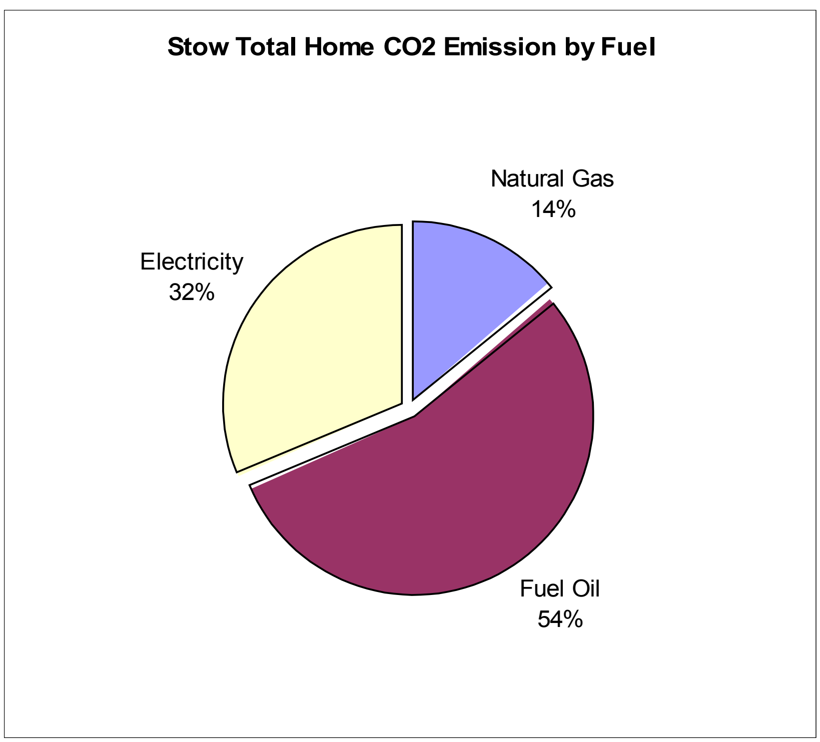
	Fuel	Total Fuel	Total Energy (Mbtu)	Total CO2 Emissions (lbs)
Household Energy Use	Natural Gas	521,883 therms	52,136	5,787,051
	Fuel Oil	1,069,344 gal	148,125	23,107,567
	Electricity	27,720,843 kwh	94,611	13,434,796
	Household Total		294,872	42,329,414

2010 Stow Home Energy Use Summary

The two charts below illustrate this data as a percentage of total home energy use and total CO_2 emissions



Stow Total Home Energy Use by Fuel



Stow Total Home CO2 Emissions by Fuel

The relatively larger contribution of fuel oil to CO_2 emissions is a result of the remarkably low CO_2 emissions of electricity provided by Hudson Light & Power. Lower than burning fuel oil directly in the home.

Average Home Energy Use

The fuels used for heating and hot water are the major factors impacting the 'energy profile' for the average home in Stow. Nearly all homes using natural gas for heating also use natural gas for hot water. Many homes with natural gas also use gas for appliances – stoves and dryers. About two thirds of homes that heat with oil also use oil hot water, the remaining third use electric hot water. Homes that that use electric heat also use electric hot water. So the primary combinations of home fuel sources and approximate percentages in Stow are:

- Oil heat and hot water – 42%
- Oil heat and electric hot water – 22%
- Natural gas heat and hot water – 20%
- Natural gas heat and electric hot water – 1%
- All electric – 9% of homes
- Other fuels (wood, propane, solar) – 6%

The chart below shows annual fuel consumption, C02 emissions and cost for the average home in Stow using each of the above fuel combinations for heat and hot water.

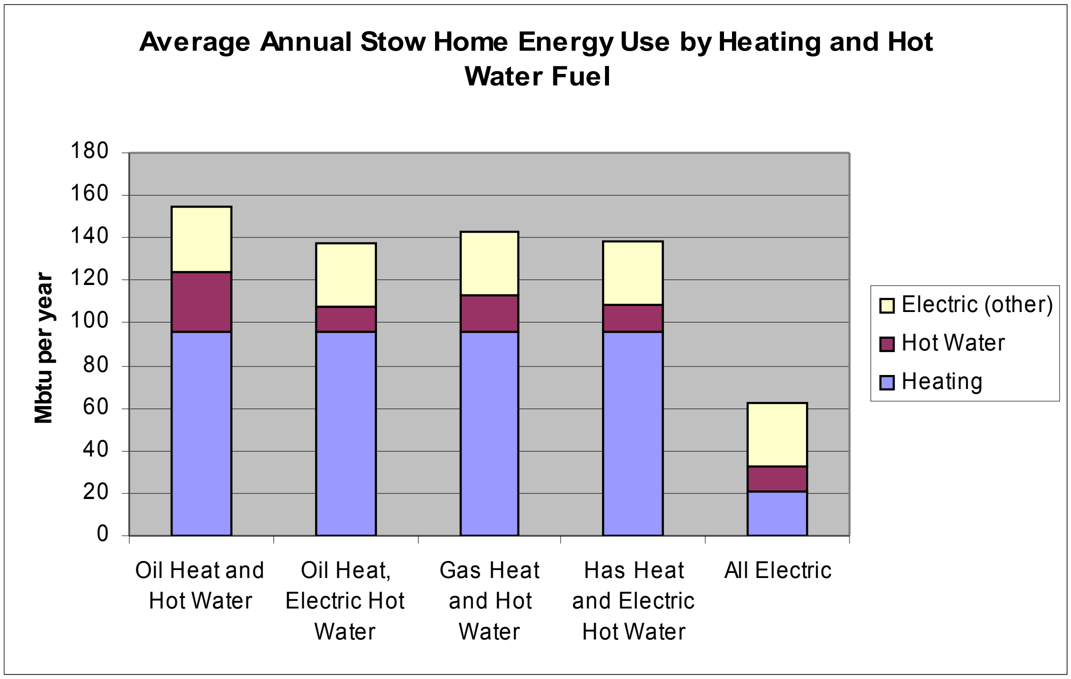
		Heating	Hot Water	Electric (other)	Total
Oil heat and hot water	fuel per year	640 gallons	189 gallons	8753 KWh	
	Mbtu	96	28	30	154
	CO2 (lbs)	14976	4423	4242	23641
	Cost	$1,792	$529	$1,182	$3,503
Oil heat and electric hot water	fuel per year	640 gallons	3384 KWh	8753 KWh	
	Mbtu	96	12	30	138
	CO2 (lbs)	14976	1704	4242	20922
	Cost	$1,792	$457	$1,182	$3,430
Gas heat and hot water	fuel per year	963 therms	174 therms	8753 KWh	
	Mbtu	96	17	30	143
	CO2 (lbs)	10689	1887	4242	16818
	Cost	$1,733	$313	$1,182	$3,228
Gas heat and electric hot water	fuel per year	963 therms	3384 KWh	8753 KWh	
	Mbtu	96	12	30	138
	CO2 (lbs)	10689	1704	4242	16635
	Cost	$1,733	$457	$1,182	$3,372
All electric	fuel per year	5997	3384 KWh	8753 KWh	
	Mbtu	20	12	30	62
	CO2 (lbs)	2906	1704	4242	8853
	Cost	$810	$457	$1,182	$2,448

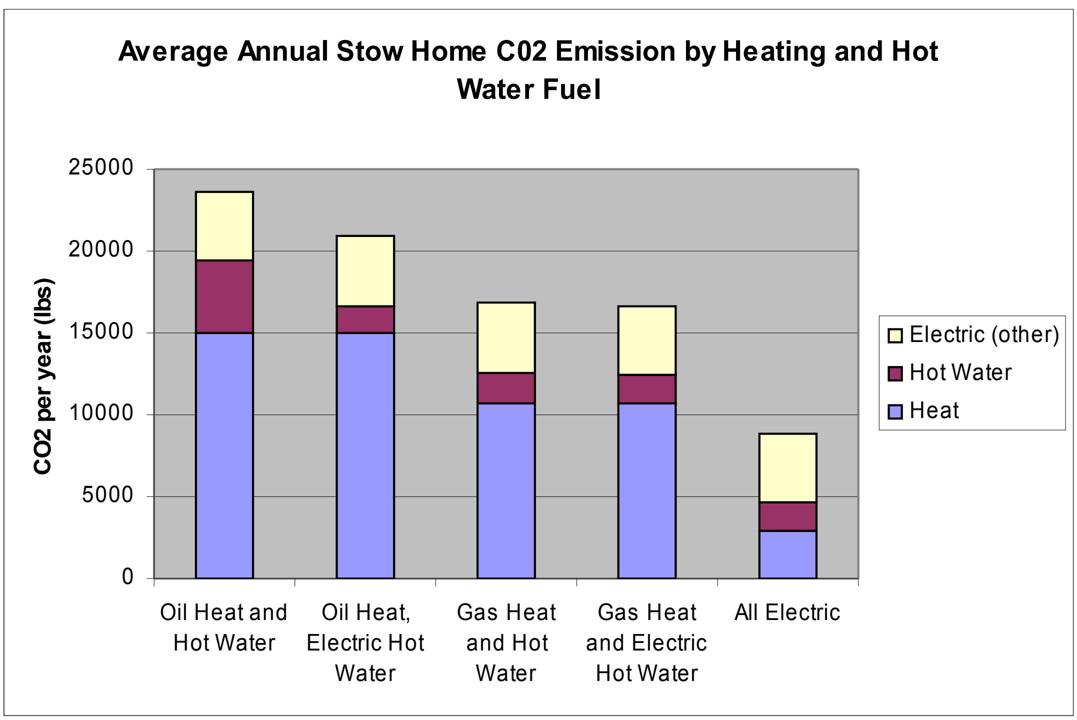
Average Stow Home Energy Use, CO2 Emissions and Energy Cost

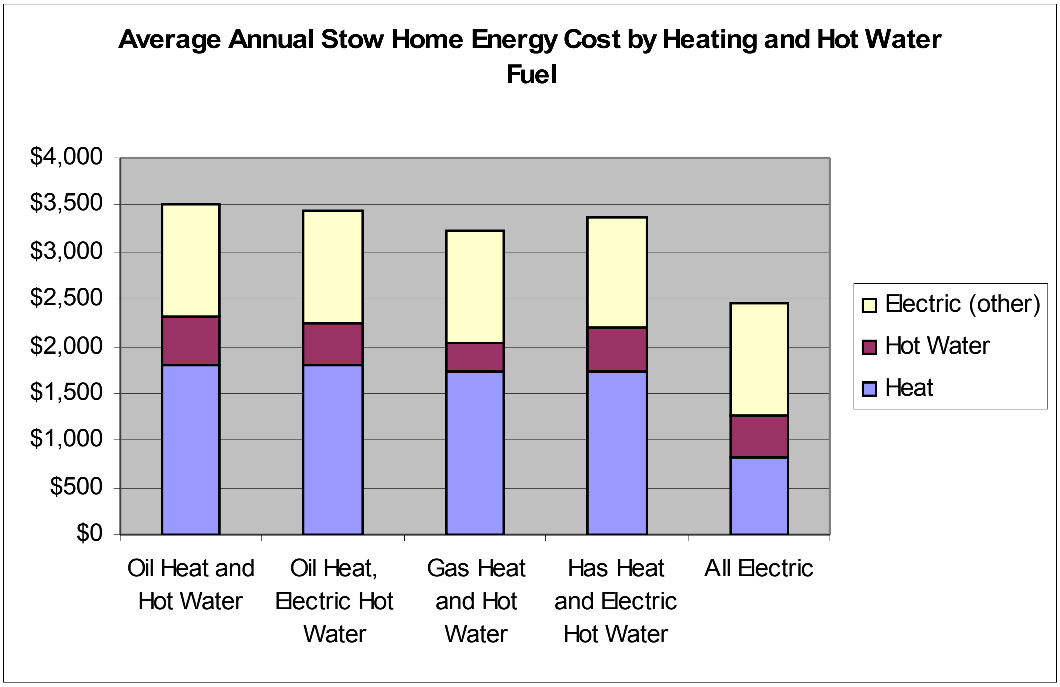
Notes:

1. Cost of fuel is based on 2009 average. Oil $2.80 per gallon, Gas $1.80 per therm, Electricity $0.135 per KWh.
2. Gas used for appliances is not broken out.
3. All hot water is assumed to be conventional storage units.
4. The column "Electric (other)" is average annual electric use other than heat or hot water (e.g.. lighting, appliances, air conditioning, electronics).
5. Additional detail can be found in Appendix B

The bar graphs below compare energy use, CO2 emissions, and cost for these home fuel mixes.


Average Annual Stow Home Energy Use by Heating and Hot Water Fuel
Mbtu per year
180
160
140
120
100
80
60
40
20
0
Oil Heat and Hot Water
Oil Heat, Electric Hot Water
Gas Heat and Hot Water
Has Heat and Electric Hot Water
All Electric
Electric (other)
Hot Water
Heating


Average Annual Stow Home C02 Emission by Heating and Hot Water Fuel
CO2 per year (lbs)
25000
20000
15000
10000
5000
0
Oil Heat and Hot Water
Oil Heat, Electric Hot Water
Gas Heat and Hot Water
Gas Heat and Electric Hot Water
All Electric
Electric (other)
Hot Water
Heat



The graphs above illustrate several points.

The lower energy use for electric hot water as compared to gas or oil is a result of the higher efficiency of electric hot water (90%) as compared to gas (60%) or oil (55%).

Energy for heating is similar for gas or oil and slightly below the Massachusetts average of 50 btu per heated square foot. On the other hand, CO2 emissions for oil are significantly higher than gas as a result of gas being about 30% 'cleaner' than oil.

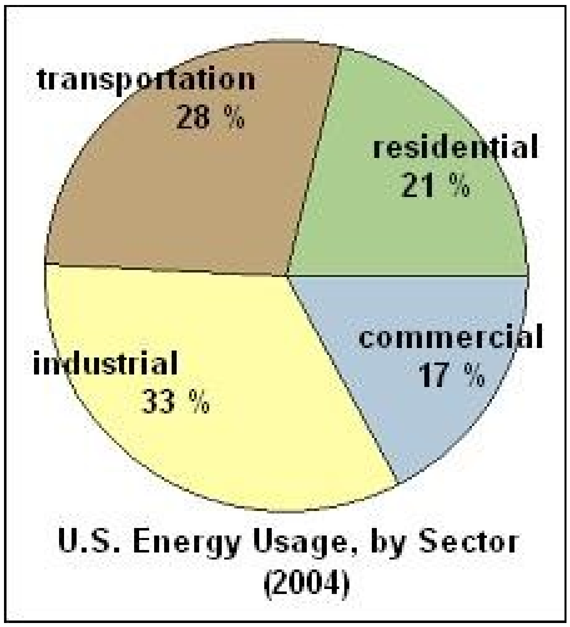
An unexpected result is that homes heated with electricity use far less energy than either gas or oil. It would be assumed the energy used for heating should be nearly independent of the fuel source. The difference is partially due to the higher efficiency of electric heating as compared to gas or oil. But this does not explain the dramatic difference. The data compiled by the RECS (Regional Energy Consumption Survey) shows similar differences in the energy used for electric heating as compared to gas or oil for all regions of the U.S. It is believed the difference is largely the result of homeowners using electric heating more carefully. Typically, house heated with electricity, have a thermostat in each room. Given this level of control, the homeowner would heat only the occupied rooms of the house. With gas or oil, a home has only a single or, at most, two or three heating zones. Combined with higher cost per unit of energy for electricity, the lower total energy used for electric heating is understandable.

Stow Residential Energy in Context

This section provides several comparisons of Stow energy use within a larger context.

U.S. Energy Use by Sector

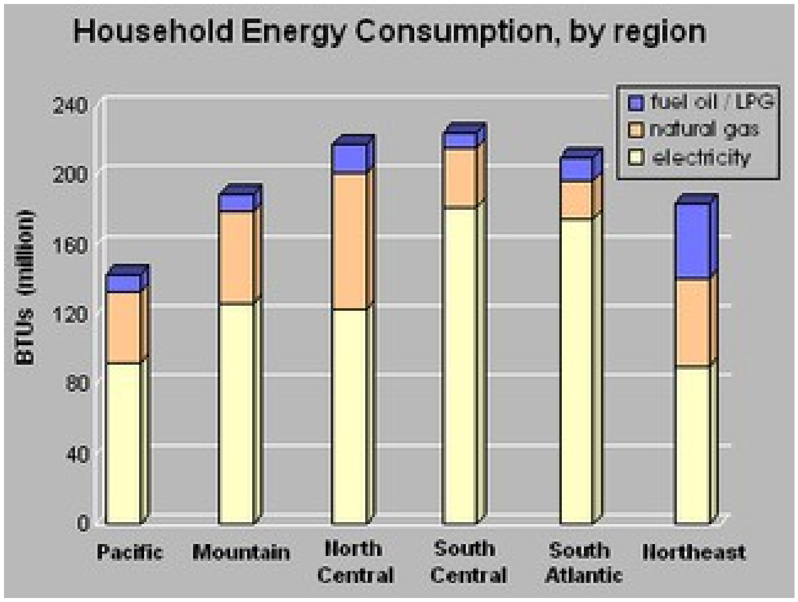
For the country as a whole, a breakdown of energy use by sector is shown below:



Within the transportation sector, approximately one third is the energy used by cars. Thus the energy profile of Stow is very different from the U.S. as a whole due primarily to the relatively small amount of commercial and industrial activity in town. As described earlier, in Stow, home energy use and private transportation account for between two thirds and three quarters of total town energy use. While for the U.S. as a whole, this accounts for about one third of energy use.

Regional Household Energy Use

Home energy use varies significantly by region as illustrated in the chart below.



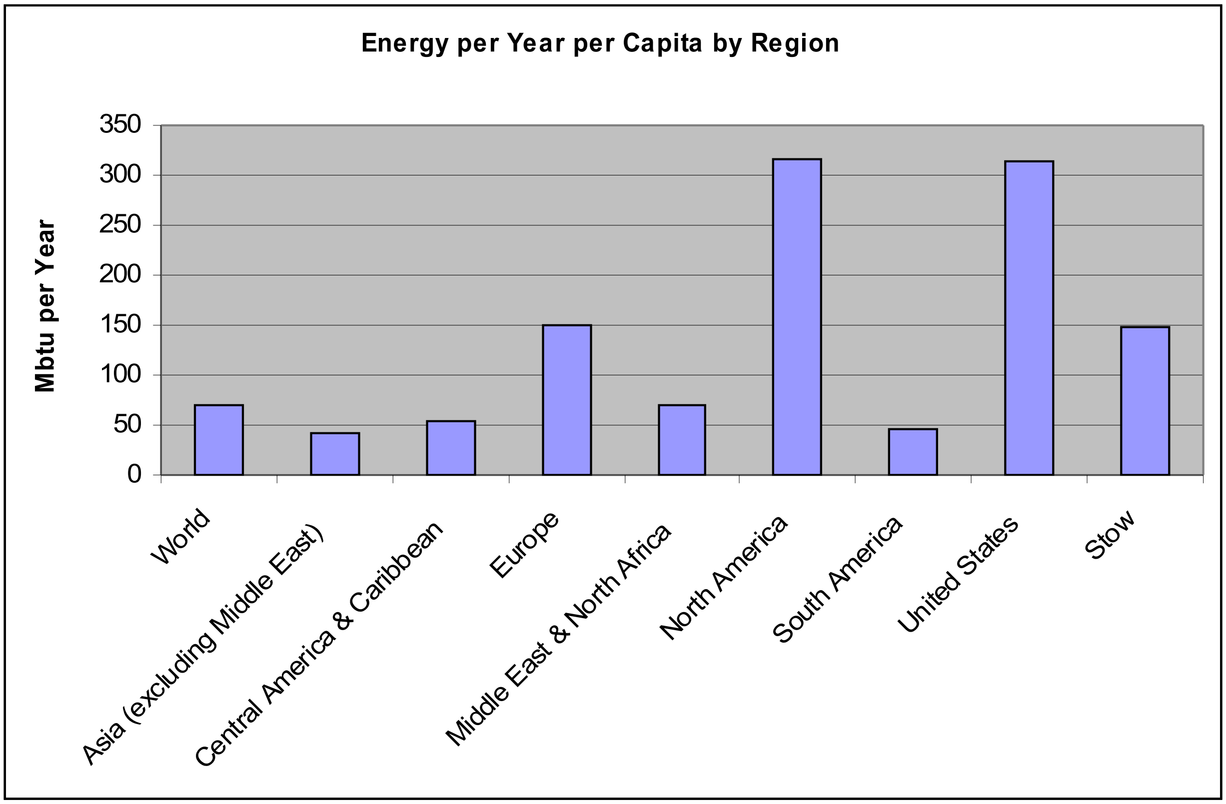
Average home energy use in Stow, about 140 million BTU per year, is roughly comparable to the average household energy use in the Northeast. Home energy use in the South Atlantic and South Central regions is significantly higher than the Northeast. As shown in the chart, this is entirely a result of much higher use of electricity for air conditioning.

Energy Use and CO2 Emissions World Wide

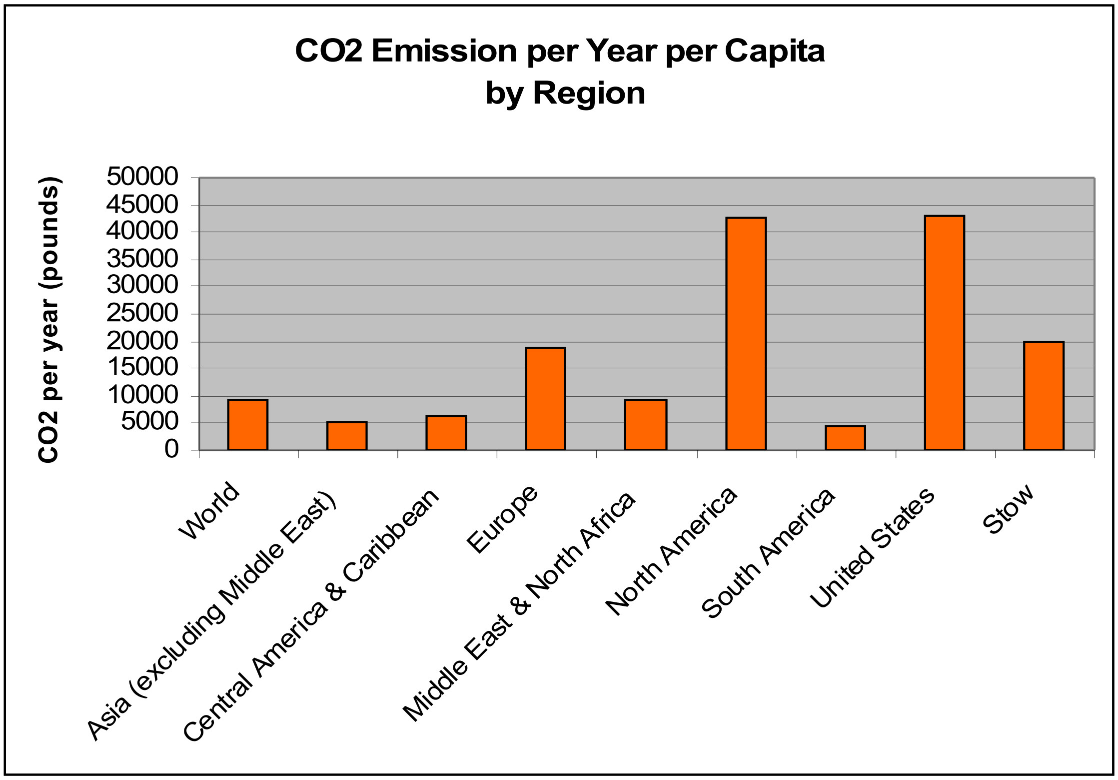
Figures on energy use in different regions of the world are available on a per capita rather than a per household basis. The chart below shows the annual per capita energy in the major regions compared to the U.S. and Stow. They represent the total annual energy consumption of a region divided by the number of residents. The figure for Stow significantly underestimates our true energy use:

As shown in the figure above displaying U.S. total energy use by sector, about two thirds of total U.S. energy is used by the commercial and industrial sectors or for non-car transportation. A significant portion of Stow's true energy use results from energy used in the creation of goods or services produced outside of Stow but used in the town. The figure shown represents only the energy used directly in our homes and vehicles.

The figure below does illustrate the disproportionate per capita energy use in the U.S. and Canada as compared to all other major regions of the world. In particular, our energy use is over double that of Europe and over four times that of the world average. As will be discussed in the section below on climate change, this imbalance is expected to decrease in certain regions of the world over the next few decades as their standard of living improves.



A similar effect is shown in comparing per capita CO_2 emission by region as shown in the chart below. Here again the U.S. and Canada, on a per capita basis, emit over four times the world average. As with energy use, the CO_2 emissions per Stow resident are significantly underestimated. It represents only CO_2 emissions resulting directly from home and vehicle use and does not account for indirect energy use for goods and services.



Stow and Climate Change

Climate Change

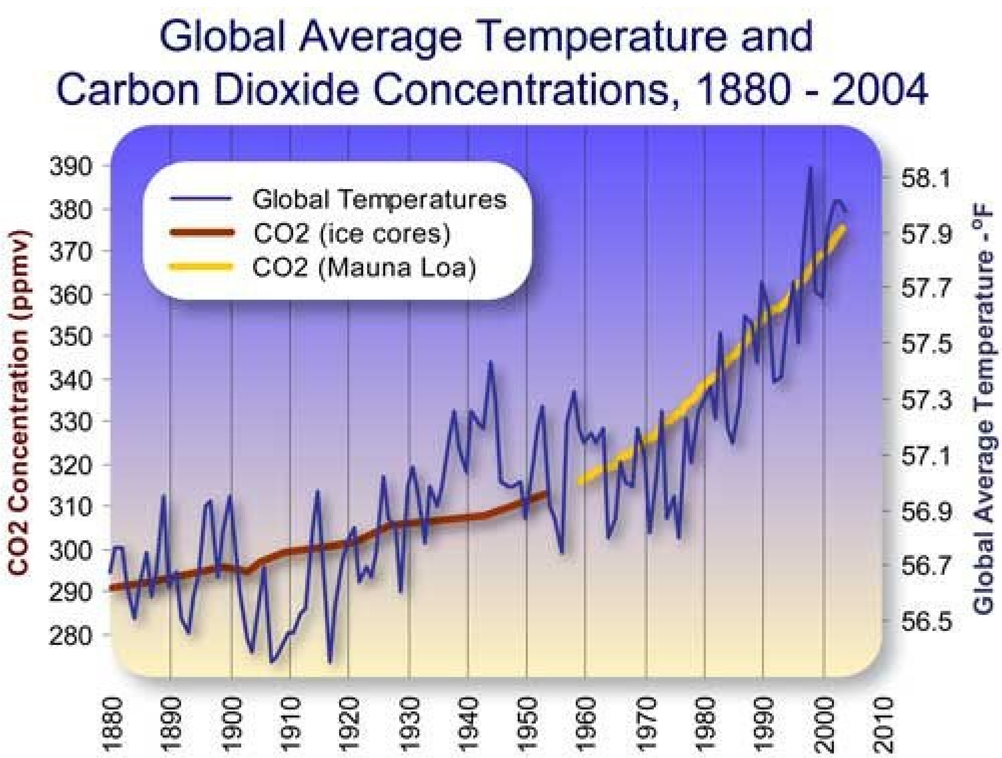
(Note – This is a very brief introduction. There are extensive discussions of climate change and global warming available. Several references are included in the Appendix)

Over the last several decades an overwhelming consensus in the scientific community emerged that climate change is occurring and is the result of human activity. The cause of climate change is a dramatic increase of greenhouse gas in the atmosphere resulting largely from the burning of fossil fuels and, to a smaller degree, by deforestation and food production.

Fossil fuels emit greenhouse gases, primarily CO2, when burned to generate energy. While deforestation reduces the total greenhouse gas 'sinks' which absorb CO2.

CO2 and other gases are called greenhouse gases because they create the 'greenhouse effect'. Solar radiation absorbed at the Earth's surface is re-radiated as thermal radiation. Some of this thermal radiation is absorbed in the atmosphere by green house gases and re-reradiated back to the earth's surface resulting in the earth's surface being warmer than it would otherwise be.

The amount of CO2 in the atmosphere has been increasing dramatically over the last 150 years and global temperatures have tracked this increase as illustrated below.



Rising temperature results in a number of impacts that are being experienced today and modeled for the future. These impacts include:

- Falling crop yields in many regions
- Threat to water supplies
- Increase in sea level
- Extreme weather

As the concentration of CO2 in the atmosphere increase, these and other effects will become more pronounced and would result in a far different world by the end of the century. Of particular concern is the potential for irreversible changes or 'tipping points'. These occur when an impact becomes self-sustaining due to positive feedback. An example could be melting of polar snow cover. As more snow melts, less thermal radiation is reflected and more is absorbed. A point may be reached where the heating effect due to less snow cover becomes irreversible regardless of the concentration of greenhouse gas.

There is not universal consensus in the scientific community as to what constitutes a safe concentration of greenhouse gas in the atmosphere. This is partially due to uncertainty in the models used to project climate change as well as differing views as to how well we will be able to adapt to the impacts of climate change. In addition, the target may be influenced by what is thought to be achievable – setting an unachievable target may not generate the action required. During the last several hundred thousand years, the concentration of CO_2 has been between 200 and 300 ppm (part per million). Today it is 387 ppm and increasing at a rate of about 2 ppm a year. The target values for stabilizing CO_2 range between 350 and 500 ppm. At the international climate conference in Copenhagen in December 2009, world leaders pledged to a target of holding the increase in average world temperature to 2 degrees centigrade. Climate modeling indicates this corresponds to a CO_2 concentration of around 450 ppm.

The Global Carbon Trajectory

An important property of greenhouse gases is that they stay in the atmosphere for a relatively long time. CO_2 stays in the atmosphere for about 100 years. Thus, the concentration of greenhouse gas is a cumulative effect. Even if it were possible, dramatically cutting greenhouse gas emissions over the space of a few years would have no immediate impact on the concentration in the atmosphere.

Thus both the physical properties of greenhouse gases and any realistic approach to reducing their concentration in the atmosphere, suggest a 'trajectory' for reduction rather than an abrupt change. To achieve a CO_2 concentration of 450 ppm, we need to be on a trajectory that results in net emissions of CO_2 by mid-century to be 80% below what they were at the turn of the century. Intermediate milestones also need to be established. These targets vary, but are in the range of a reduction of 20% by 2020.

There are major challenges to dramatically reducing the generation of greenhouse gas. The increase in greenhouse gas since the start of the industrial revolution is directly tied to both economic and population growth. Prosperity has been driven by increased energy use for transportation, manufacturing, food production, and our ability to live comfortably in a variety of climates. Our way-of-life is dependent on abundant energy. The solution must combine both using less energy – through conservation and efficiency – and employing means of generating carbon-free energy.

Action by concerned individuals, while important and necessary, will not result in the change needed. Market forces, without strong incentives or regulations, will also not bring about change. The supply of fossil fuels, coal, oil, and natural gas, while not unlimited is estimated to be sufficient to continue to supply our energy requirements for well over a century at reasonable costs for the fuel itself [note 1]. The release of CO_2 into the atmosphere when fossil fuels are burned has no immediate and direct impact. Climate change is the long-term cumulative effect of burning these fuels. Without a mechanism to account for this impact, the direct cost of production will be the only factor considered in energy production. This mechanism may use market forces, but will only come about by legislative action demanded by the public. A number of means are available:

- A ‘carbon’ tax
- Cap and trade
- Mandated emission standards

As it must be, the 80% reduction in greenhouse gas emissions is a global target. If certain regions commit to the target without similar commitments from all major greenhouse gas producers, the target will not be met.

These targets are a major challenge. However, global trends make them even more daunting.

World population will continue to increase through mid-century. Current forecasts indicate a growth from a current population of 6.9 billion to 9.1 billion by 2050 at which point world population would level off. In addition, many developing countries have rapidly increasing standards of living.

These factors result in projections of much higher demand for energy and food over the next 40 years – making the 80% percent reduction in greenhouse gas by mid-century a still greater challenge. For example, in the absence of new national and international regulations, it is projected the emissions energy-related CO_2 will increase by 43% over the next 25 years.

The Carbon Trajectory in Stow

Until the beginning of the twentieth century, Stow was primarily a farming community and vacation spot for residents in the immediate Boston area. Trolley service was introduced in 1901 and cars were rare until the late 1920’s. Stow become the community it is today as a result of the wide spread introduction of new technologies enabled by abundant, low cost energy:

New and improved roads along with affordable cars and low cost gasoline enabled an increase in population where most new residents commuted to work. Central heating and hot water was provided by way of low cost oil, electricity, and natural gas. Improvements in quality of life through new household appliances and electronics became available through advances in technology, production, and abundant energy.

As Stow transitioned from farming to a, primarily, suburban community, the population increased from 1,240 residents in 1940 to over 6,500 today. The town’s carbon footprint increased with the population and the dramatically higher energy consumption per resident. The only significant area where our net CO_2 emissions have decreased is in the reforestation of much of the town as land used for pasture, farming, and firewood grew into second generation forests. However, it is likely the energy consumed in growing and transporting the food we now eat, more than offsets the ‘carbon sink’ of our reforested town.

It is safe to assume the overwhelming majority of the town envisions a Stow 40 years from now that more closely resembles the town as it is today than as it was 100 years ago. That is to say, we will continue to live in single-family detached homes, many, if not most, are the homes we live in today with central heating, modern appliances, and whatever future wonders are provided through consumer electronics. And, we will continue to rely on cars for much of our transportation requirements. If we also wish to live in a climate similar to today’s, we must participate in the global effort to reduce greenhouse gas emission. A reasonable target for Stow would be the same as that adopted by the international community in Copenhagen:

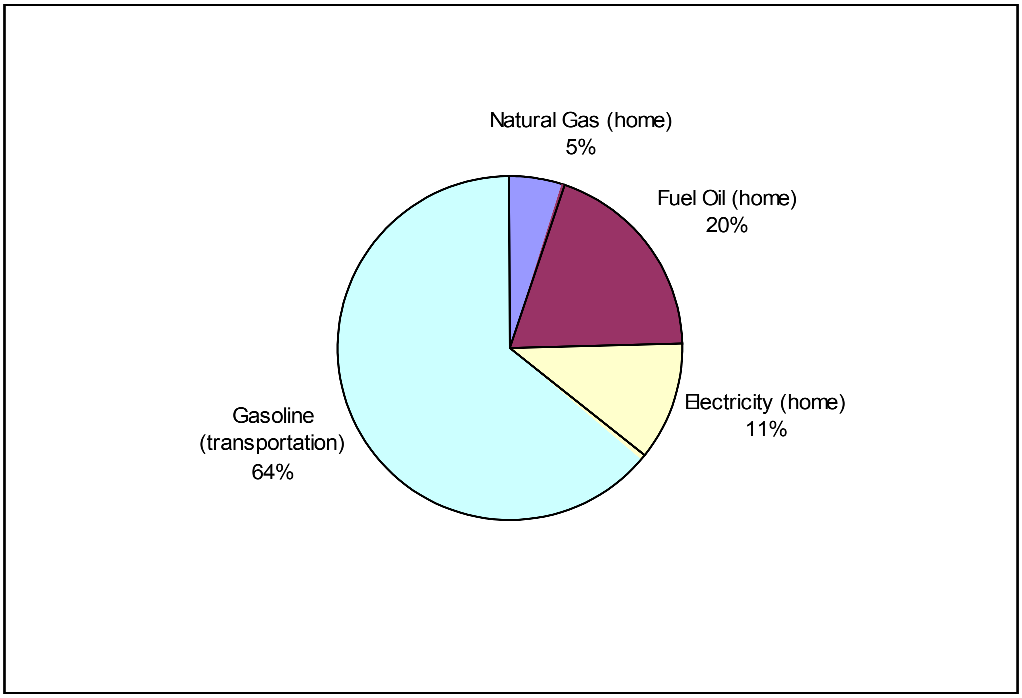
- 20% reduction in greenhouse gas by 2020
- 80% reduction in greenhouse gas by 2050

Several states including Massachusetts have enacted laws regulating the emission of greenhouse gas in the state. In 2008, the Global Warming Solution Act (MA S. 2540) was signed into law. This bill commits the commonwealth to a 10 to 25 percent reduction from 1990 emissions by 2020 and an 80 percent reduction by 2050.

The commonwealth has also adopted several other initiatives designed to reduce our carbon footprint:

- Green Communities Act
- California vehicle emissions standards
- RGGI

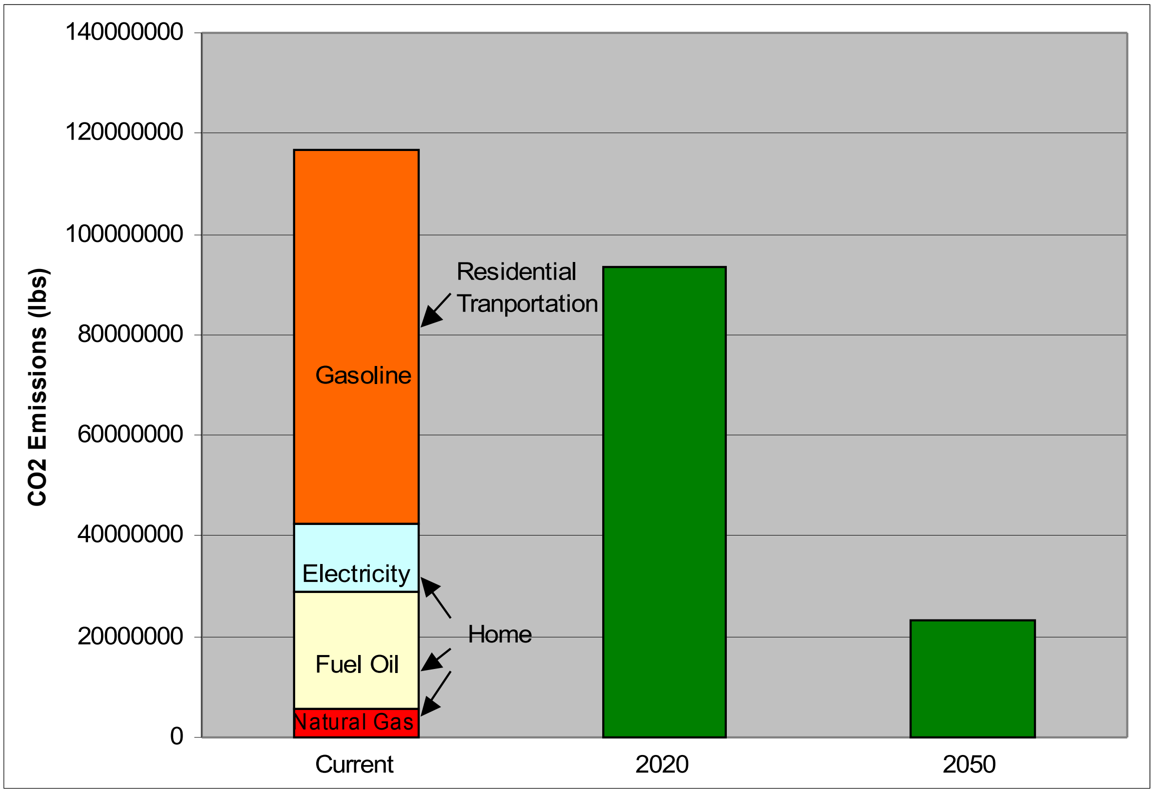
In the previous sections, our residential CO2 emissions were calculated. The chart below shows current CO2 emissions by energy source and use.



Stow Residential CO2 Emission by Fuel Type and Use

This illustrates our “ rural suburban” emission profile and the relatively small contribution to emissions from electricity resulting the “clean” power provided by Hudson Light & Power.

The bar graph below shows our current CO2 emissions and our targets for 2020 and 2050 – 20% and 80% reductions respectively. As discussed earlier, our residential emissions account only for energy used directly in the home and for private transportation – it does not include the energy for the goods and services we use. In examining Stow’s carbon trajectory from our current emissions to the 2020 and 2050 targets, town population increases will not be considered. Our current population is 6,600. Estimates are a population of 6,775 in 2020 and 6,990 in 2030 with a potential ‘build out’ population of 9,582 given current zoning bylaws. Nonetheless, climate change is a worldwide challenge. As discussed earlier, emissions targets are absolute regardless of population growth. For Stow, the relatively small increase in population projected for 2020 would not have a significant impact on our 2020 emission target. However, if in 2050 the population is 8,000, than the *per capita* emission reduction would need to be 84% rather than 80% to meet the town-wide goal of an 80% emission reduction.



Current Stow Residential CO2 Emissions and Targets for 2020 and 2050

Meeting the 2020 Emission Target (20% CO2 emission reduction)

Stow will not be on its own in targeting substantial emission cuts by 2020. As noted above, the state has committed to an even greater overall reduction in emissions and there is support for this level of reduction at the federal level as well.

The Massachusetts goal is a 25% reduction in GHG (Greenhouse Gas Emission) as compared to a 1990 baseline by 2020. The goal is further refined by targeting reductions in the following sectors as shown in the table below.

Sector	Percent GHG Reduction
Buildings	9.8%
Electric Supply	7.7%
Transportation	7.6%
Non-Energy	2.0%
Total	**27.1%**

Massachusetts 2020 Emission Reductions by Sector

As a community of Massachusetts, we will participate in meeting these goals. Our contribution must rely on local participation but must also leverage initiatives at the state and federal level. However, our emission reduction targets will be different than those of the state as a whole:

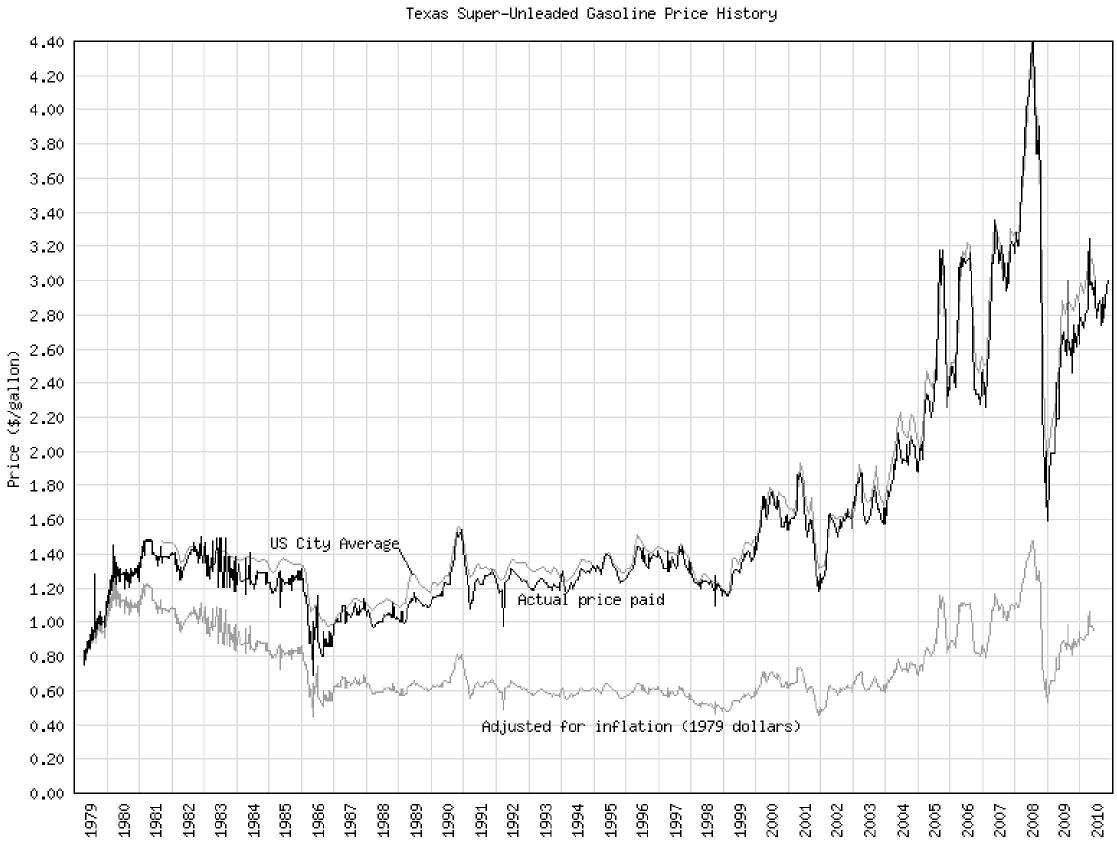
- Our energy and emissions profile is different. At the state level, over 50% of energy is used in buildings and they are the greatest source of GHG emissions. In Stow, our homes contribute 36% of emissions.
- As shown in the table above, at the state level over a quarter of the targeted emission reductions come from reducing GHG emissions from the supply of electricity. In Stow we already have a cleaner electric supply from Hudson Light & Power than the state is targeting for 2020. Because of the premium on clean electric generation, it is not expected that Hudson Light & Power can significantly further reduce emissions over the next 10 years. It may seem we are penalized unfairly by already having achieved this goal. But this represents our local emissions baseline.

Stow Residential Transportation

The major source of residential CO_2 emission in Stow is the gasoline burned for private transportation. Several factors indicate there can be a significant reduction in emissions from this sector by 2020:

- New CAFE (Corporate Average Fuel Economy Standards) increase the average passenger car fuel economy from 27.5 mpg in 2010 to 39 mpg in 2016
- Increase in work-from-home employment. The 2000 census show 5.8% of workers in Stow worked at home. Data for 2005 – 2009 shows that figure increased to 9%
- Increased sales of hybrid and plug-in hybrid cars. Currently, hybrids represent 2.5% of car sales. This is expected to double by 2020.
- Proposed state initiatives to provide incentives to drive fewer miles and increase use of public transportation. One promising approach is called Pay As You Drive (PAYD). This is an automotive insurance policy that would base premiums on the annual mileage driven.

A major unknown is the price of gasoline over the next 10 years. Higher fuel prices result in a larger market for fuel efficient cars and more thoughtful planning of trips to decrease mileage. However, forecasts of 'peak oil' not withstanding, the historical price of gasoline, adjusted for inflation has remained relatively flat over the last 30 years as shown in the figure below.



Actual and Inflation Adjusted Price of Gasoline

Assuming the percentage of work-from-home employment continues to increase at the same rate it has over the last 10 years, by 2020 about 17% employment will be work from home

Home Fuel Oil

Home fuel oil is the second largest contributor to residential CO2 emissions. With the relatively small projected population increase between now and 2020, it is expected the housing stock in 2020 will be largely what it is today. Over half the homes in Stow were built after 1970. Reductions in home fuel oil use may result from:

- Home weatherization and boiler upgrade. For older homes, fuel savings of up to 25% are possible.
- Lowering the thermostat. Energy savings of about 1% result from each degree of setback for a setback period of eight hours a day.

- As with gasoline, probably the greatest impact and the greatest unknown is fuel cost. If the cost of fuel oil continues to trend up over the next ten years, we will have a greater incentive to take measures to reduce our energy use.

Electricity

As discussed in Appendix A, Stow already enjoys remarkably clean electricity – largely a result of long-term contracts for nuclear generated electricity from Seabrook. CO2 emissions per unit of delivered electricity are well under half that of the country as a whole. Put another way, we are already at the level of emissions for electric generation that the U.S. targets for 20 years from now. Given the demand for clean electricity in Massachusetts driven, in part, by the needs of investor owned utilities to meet the RPS (Renewable Energy Portfolio Standard) requirements and the scarcity of new, clean generation capacity, it is unlikely that Hudson Light & Power will be able to find additional sources of clean yet affordable electricity over the next 10 years.

Currently, 86% of total residential electric use in Stow is used for purposes other than heating and hot water. Based on national averages, this electricity is used as shown in the table below.

Use	Percent Electric Consumption
Lighting	29%
Air Conditioning	27%
Refrigeration	20%
Electronics	12%
Wet-clean (most clothes dryers)	12%

Residential Electric Use Exclusive of Heat and Hot Water

The efficiency of refrigerators has increased dramatically over the last 20 years with impressive improvements in air conditioners and washer/dryers as well. Energy Star rated products today are from 25% to 50% more efficient than older models. Another significant impact on residential electric use is the phase out of incandescent lighting. The federal *Energy Independence and Security Act of 2007* will require all general-purpose bulbs to have efficiency similar to CFLs (compact fluorescent lamp) by 2020 – an energy savings of about 75%.

Natural Gas

Natural gas makes the smallest contribution to CO_2 emissions of the primary residential fuel sources in Stow. As with fuel oil, significant efficiency improvements, particularly in older homes, are possible through weatherization and, in some cases, boiler upgrades.

2020 Emission Outlook

Based on the discussion above on the outlook for residential energy use, below are tables estimating residential emissions reductions in Stow for transportation and housing.

Residential Transportation	**Transportation Reductions in CO2 Emissions**
Car Fuel Efficiency (CAFÉ, hybrids) Note 1	22%
Reduction in VMT (PAYD) Note 2	1%
Increase Work-From-Home Note 3	2%
Total Transportation Reduction	**24%**

Estimate of CO2 Reduction from Residential Transportation in 2020

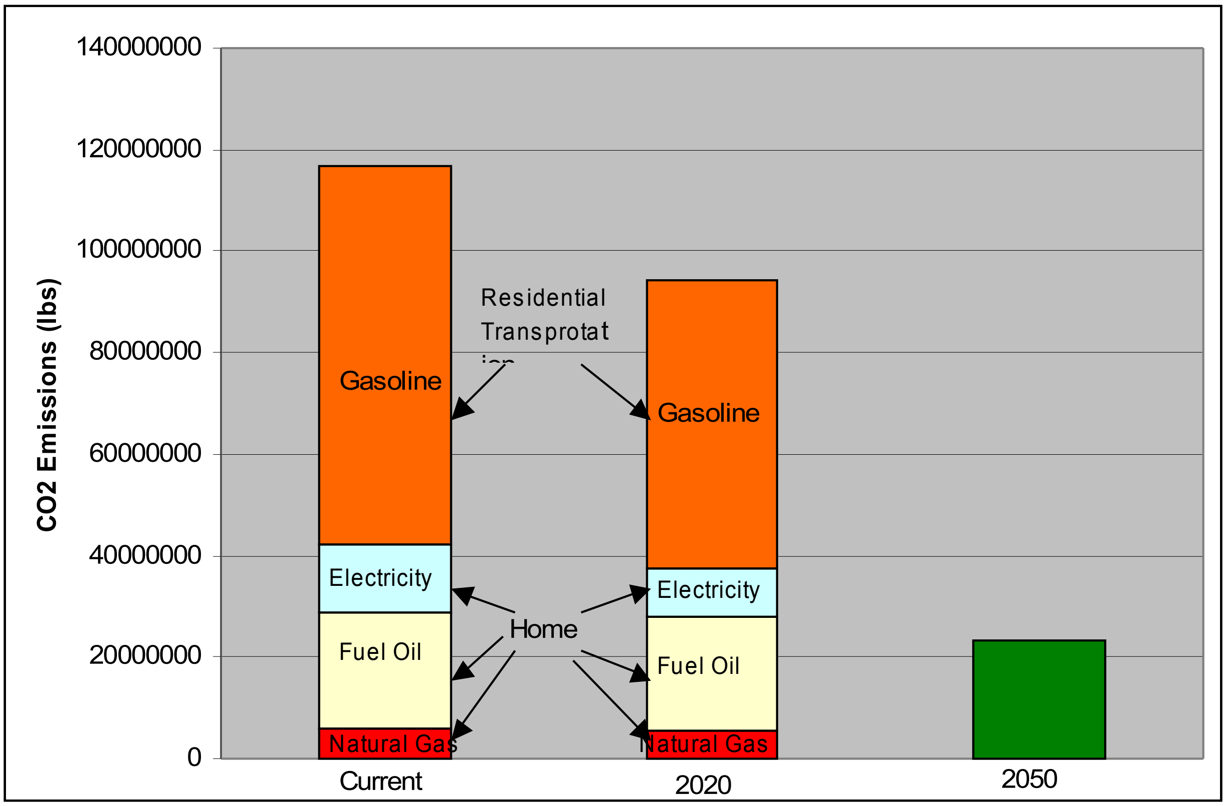
Notes:
1.) Assume a third of vehicles in 2020 meet the 2016 CAFÉ standards.
2.) Per Massachusetts 2020 estimate
3.) Assume additional 8% work-from-home

Home	**Home Reductions in C02 Emissions**
Appliance and Lighting Efficiency Note 1	9%
Heating Efficiency (Weathearization and Boiler upgrade) Note 2	1%
Heating Conservation (thermostat setback) Note 3	2%
Total Home Reduction	**12%**

Estimate of CO2 Reduction from Housing in 2020

Notes
1.) Assumes 90% upgrade to CFL efficiency lighting and 25% upgrade to EnergyStar appliances
2.) Assumes 20% of homes 50 years or older are weatherized with a fuel savings of 15% on average
3.) Assumes 20% of homes do a setback of 3 degrees for 8 hours during heating season

The above estimates of a 24% reduction in emissions from residential transportation and a 12% reduction from home energy use, yield a total residential energy reduction of almost 20% overall as illustrated below.



Current Residential Stow C02 Emission with Estimate for 2020 and Target for 2050

We found it is reasonable to meet the 2020 emissions target through energy efficiency and conservations measures alone. It was neither necessary nor realistic to expect a significant reduction in emissions by switching to cleaner sources of energy. However, as discussed below, further improvements in efficiency and conservation measures, while needed, will not achieve the emissions reduction target for 2050.

Meeting the 2050 Emission Target (80% CO2 Reduction)

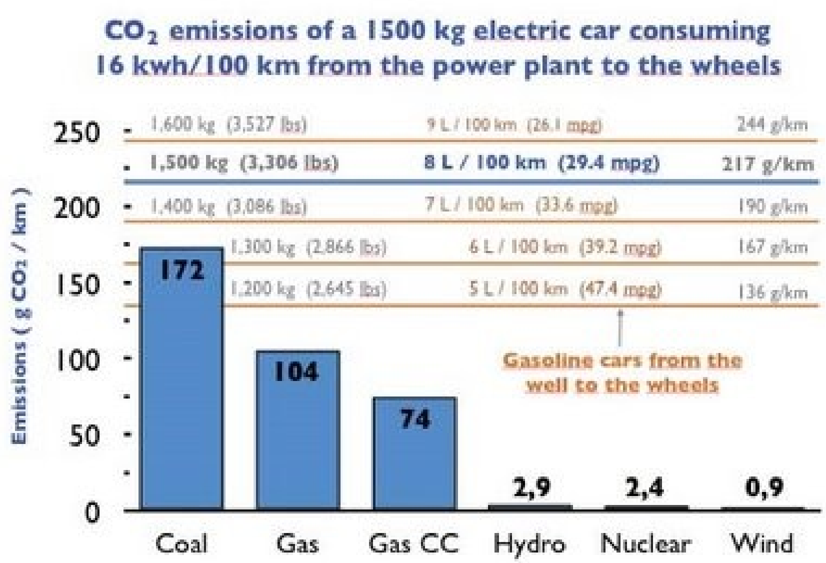
While it is reasonable to achieve the 2020 emissions target through energy efficiency and energy reduction, this approach won't achieve the 2050 target of an 80% reduction in CO2 emissions. Current emissions from fuel oil alone for heating and hot water (20% of current total emissions) represent the entire target for residential emissions in 2050.

While it isn't realistic to project precisely how the 2050 target will be met, the broad outline includes the following key components:

- Continue to focus on energy efficiency and conservation.
- Transition electric generation entirely away from fossil fuels (Note 2).
- Transition from the use of fossil fuels in general, particularly in transportation and replacement with electricity and biofuels.

Since private transportation is the largest contributor to residential CO2 emissions in Stow, it will be necessary for our automobiles in 2050 to have virtually no net CO2 emissions. Continued improvements in fuel efficiency and broad adoption of hybrid and plug-in hybrid cars will be a helpful transition. However, a doubling or even tripling in mpg, while continuing to use gasoline, will not achieve the goal.

Electric cars with a stated 100 mpg or greater are now being introduced (Note 3). However, electric cars can achieve the goal of virtually no net CO2 emissions only when their source of electricity is carbon free. The figure below illustrates this point.



CO2 Emissions of Electric Compared to Gasoline Powered Cars

As shown above, a standard gasoline powered car with 29.4 mpg has higher, but not dramatically higher, CO_2 emissions as compared to an electric vehicle when coal is used for the generation of electricity. Only when clean energy sources – hydro, nuclear, wind – are used for electric generation do electric vehicle CO_2 emissions approach zero.

Not only will the generation of electricity in 2050 need to have nearly no CO_2 emissions, we will also be using significantly greater amounts of electricity as traditional fossil fuel energy is phased out. Thus, not only will current fossil fuel electric generation capacity need to transition to clean energy sources, additional clean energy capacity must be added. As additional capacity is added, particularly from renewable sources, a new 'smart grid' electric transmission and distribution infrastructure will be needed to handle these disperse, and intermittent sources.

These changes represent dramatic but achievable challenges and will be met only through local, national, and international commitment. In Stow, we can do our part through active participation and by making sure our voice is heard in support of the measures required to meet the threat of climate change.

Appendix A: Greenhouse gas emission for different fuel sources

Greenhouse gas emissions vary dramatically depending on fuel source. For fuel oil and natural gas used in the home, energy is extracted directly from the fuel source. Except for cases where the homeowner has his own photovoltaic solar panels, electricity is delivered to the house along transmission lines. In almost all cases the electricity delivered to the home by the utility is from several remote generation plants using different sources of fuel. Thus the greenhouse gas emission for electrical use depends on the mix of fuel sources used in the generation of the electricity.

Greenhouse gas emissions for different fuel sources

The CO_2 emissions per unit of energy for fossil fuels is shown in the table below.

Fuel	C02 Emission (lbs per mbtu)
Coal	205
Natural Gas	111
Oil	156

Coal emits about twice the CO_2 of natural gas while is midway between natural gas and coal.

Primary and Secondary Energy Sources

The calculation of the greenhouse gas emission for a fuel source depends on whether the fuel is a *Primary* or *Secondary* energy source. A primary energy source is a fuel that is converted onsite to energy. Home heating oil and natural gas burned in the home for heating and hot water are primary sources of energy. However, essentially all electricity is generated at remote power plants and delivered to the home over the electric transmission and distribution grid. Fuel used to generate electricity this way is a *secondary* energy source.

For electricity generated by fossil fuels, the energy content of the fossil fuel used to generate the electricity is far greater than the energy of the electricity delivered. This is due to the efficiency of generating the electricity and transmission losses in delivering the electricity from the power plant to the home. Since more fossil fuel is used to generate and deliver a unit of electrical energy to the home than to generate the same amount of energy when the fuel is burned directly in the home, the amount of CO_2 emitted per unit of energy is also greater. In fact, more than three times the amount of energy and CO_2 is emitted when fossil fuel is used to generate electricity than to deliver the same amount of energy by burning the fuel directly – as a primary energy source – directly in the home.

The EPA (U.S. Environmental Protection Agency) uses the term *source-site ratio* to reflect the actual amount of fuel used, by an energy source (*source energy*) to deliver a unit of energy to the home (*site energy*).

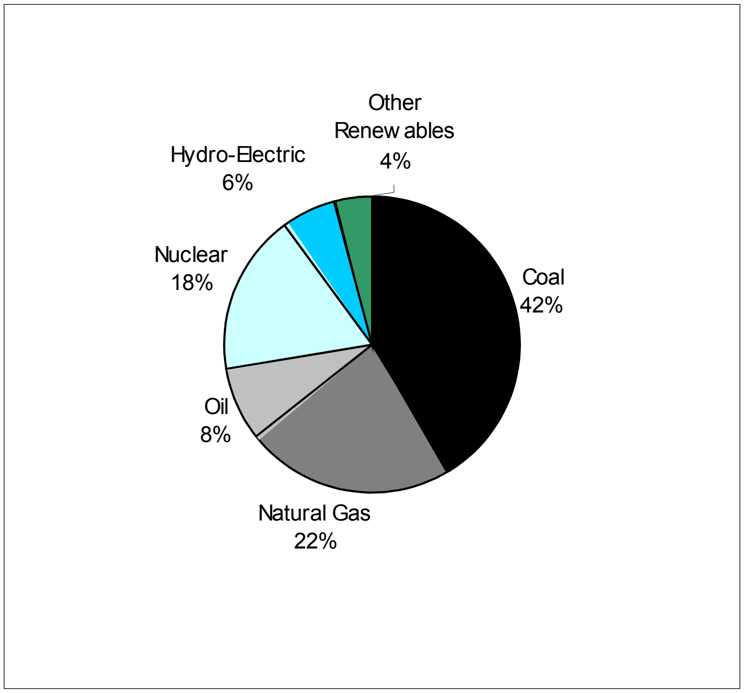
For primary fuel sources, used directly in the home, heating oil and natural gas, the source-site ratio is just slightly more than one. This reflects small losses in delivering the fuel to the house. For example, pipeline loss for natural gas. However, for secondary fuel sources used in the generation of electricity, the source-site ratio is high.

For electricity generated using fuels that emit greenhouse gas when burned, the efficiency of the generation and the losses incurred in delivering the generated electricity to the home must be factored in to determine the actual amount of greenhouse gas generated per unit of energy delivered to the home.

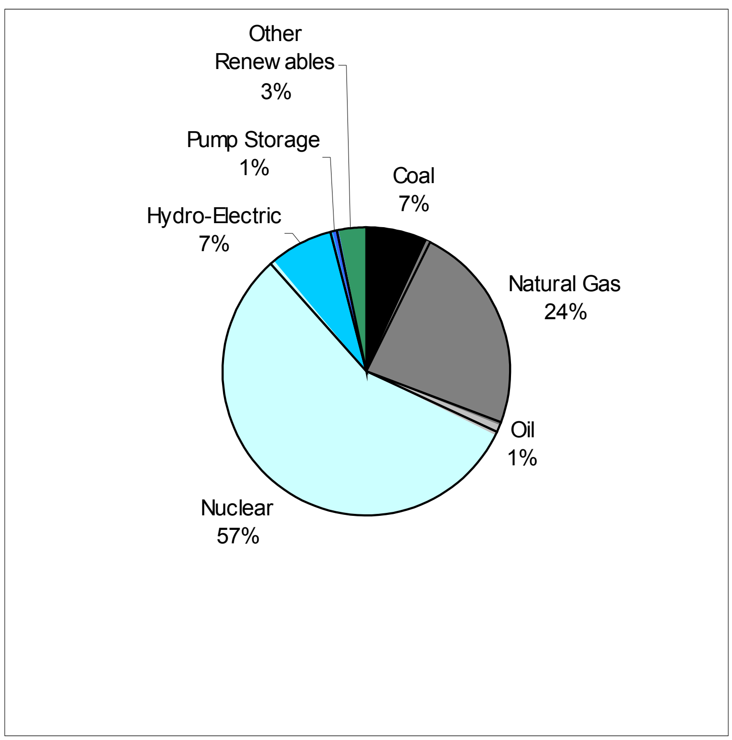
The Source-Site ratio used by EnergyStar for electricity provided from the electric grid is 3.34. This reflects an efficiency of electric power generation of about 33% for fossil fuels - coal, natural gas, and petroleum. And a transmission loss is about 10%. Thus the fuel mix used to generate our electricity is vitally important. Fossil fuels emit CO_2 and because of inherent losses associated with the generation and delivery of electricity, much more fossil fuel, and hence much more CO_2, is used to provide electricity than when the fuel is used directly in the home.

Fuel Sources for Electric Generation

The two charts below illustrate the fuel mix for the generation of electricity for the U.S. as a whole and for Stow with our electricity provided by Hudson Light and Power.



U.S. Average Fuel Mix for Electricity (2010)



Stow Fuel Mix for Electricity (2009) – data courtesy of Brian Choquette, Assistant Manager Hudson Light and Power

The two charts illustrate the dramatic difference in the use of fossil fuels for the generation of electricity between the U.S. as a whole and Stow – by way of Hudson Light and Power. In the charts the black and gray slices represent electricity generated by fossil fuels – coal, oil, and natural gas. The blue and green color slices represent electricity generating by non-emitting sources – nuclear, hydro electric, and other renewables. For the U.S. as a whole 72% of electricity is generated from fossil fuels and 26% is generated from non-CO2 emitting sources. For electricity in Stow from Hudson Light and Power, it is almost the reverse, 32% is from fossil fuels and 68% is from non-CO2 emitting sources.

With the Source-Site ratio, the percent of fuel used to generate electricity and the CO2 emission for each fuel, the greenhouse gas emission per unit of electric energy delivered to the house is calculated as follows:

(CO2 per unit of energy delivered) = (CO2 per unit of energy generated) * (source-site ratio)

And the CO2 per unit of energy generated is just the sum of percentage of each fuel times its CO2 emission per unit of energy generated. This calculation is an estimate of CO2 emissions. It has been accurate to within 7% of actual CO2 emission when compared with data from the EIA (U.S. Energy Information Administration) and is used in the tables below to provide a common base of comparison.

Using the formula above and the fuel mix for the generation of electricity, the table below shows the CO2 emissions per unit of delivered energy for the U.S. as a whole and Stow. Also shown for comparison is the average CO2 emissions for electricity consumed in Massachusetts (2005).

	CO2 Emissions (lbs per Mbtu)
U.S Average	443
Mass Average	272
Stow (Hudson Light &Power)	143

The table above illustrates the dramatic difference in CO2 emissions resulting from the generation of electricity depending on the fuel mix. In Stow, we have remarkably clean electricity. The CO2 emissions per unit of energy delivered to our homes is less than result from burning fuel oil directly in the house. On the other hand, the U.S. average for CO2 emissions is more than twice that of burning coal directly – as a result of the inherent inefficiencies in generating electricity from fossil fuel and delivering it to the home.

Greenhouse Gas Emissions from Electric Generation with Fossil Fuels

In the calculations above, it has been assumed the CO2 generated from burning fossil fuels is released directly to the atmosphere and the heat generated as a by-product of the electric generation is lost. For the vast majority of electric generation plants today, these assumptions are correct. However, there are technologies that can mitigate the CO2 emissions. Below are brief descriptions of these trends and technologies.

Overall, they are promising and, can reduce the issues of using fossil fuels. However, the current view is they are best seen as a 'bridge' to a future where essentially no fossil fuels are used in the generation of electricity.

Transition From Coal to Natural Gas

Over the last twenty years there has been a significant transition from coal to natural gas for the generation of electricity. In 1990, only 10% of electricity in the U.S. was generated from natural gas while it is over 20% today. It is expected this trend will continue over the next 20 years with the size of natural gas reserves increasing and regulations for CO2 emissions from the generation of electricity come into effect. Natural gas emits about half the CO2 of coal per unit energy. Significantly, there are almost no plans for new coal fired electric generation plants in the U.S. Concerns over the added costs associated with mitigating greenhouse gas emissions combined with the low price of natural gas, as well as decreased demand for added generation capacity over the last two years have combined to reduce the market for new coal fired electric plants.

Combined Heat and Power (CHP)

All power plants emit heat during electric generation. Combined heat and power (CHP) captures some of the by-product heat for heating purposes. For CHP to operate efficiently, the power plant and the consumer should be nearby to avoid losses in piping the heat. In the U.S. the largest example of CHP is Manhattan.

Combined Cycle Power Plant (CCPP)

Combined cycle plants use the heat generated from the primary electric generation to power a secondary turbine to generate additional electricity. This technology increases the overall efficiency of electric generation and efficiencies approaching 60% may be achievable.

Carbon Capture and Sequestration (CCS)

The approach of carbon capture and sequestration (CCS) is to capture essentially all the CO2 emitted in the process of electric generation. The captured CO2 is then piped underground or under water to a geological formation where it would be permanently stored. CCS is sometimes also called 'clean coal'. The feasibility of CCS on a large scale has not been demonstrated and no commercial plants currently employ it. It may also be the case that the added cost of using CCS would make fossil fuels uneconomic compared to other clean sources of electricity.

Appendix B: Home Energy Use in Stow

The primary residential sources of energy are:

- Electricity
- Home heating oil
- Natural gas

Hudson Light and Power provided excellent data on residential electric use in Stow. For heating oil use, Dunn Oil, one of the fuel oil providers for Stow, provided data for average annual consumption. No Stow specific data was found for natural gas or propane. For natural gas usage the Nstar state average was used. Propane use for heating, hot water and appliances is small in Stow and not considered in the survey.

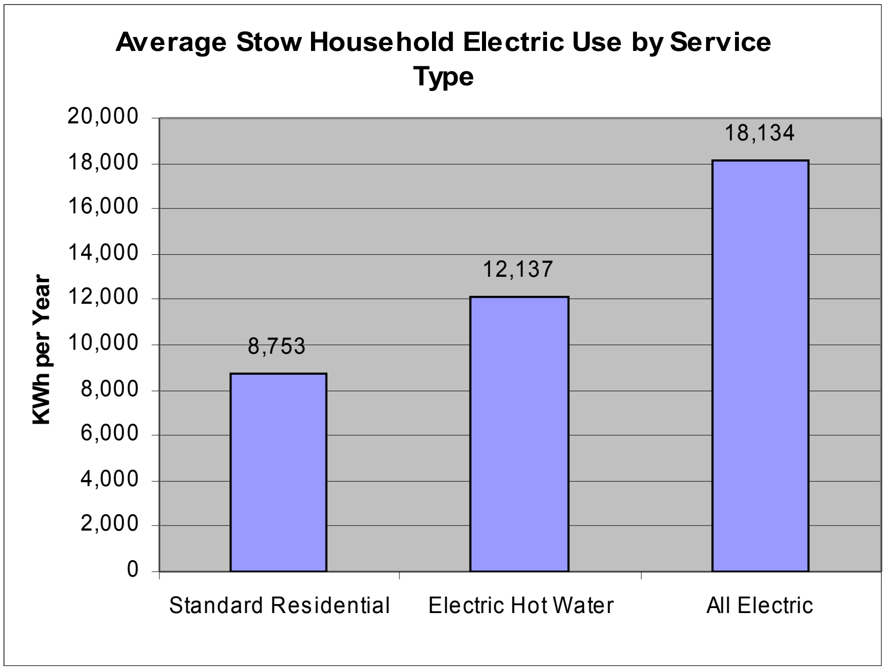
Stow Electric Use

Stow residential electric use in 2009 is shown in the table below (data courtesy Hudson Light and Power).

RATE	Service	Number of Customers	kWh	KWh/customer/ year
1 (Service "A")	Residential	1,974	17,278,243	8,753
6 (Service "E")	Elec Hot Water Heater	578	7,015,355	12,137
7 (Service "F")	All-Electric	189	3,427,245	18,134
Total		**2,741**	**27,720,843**	

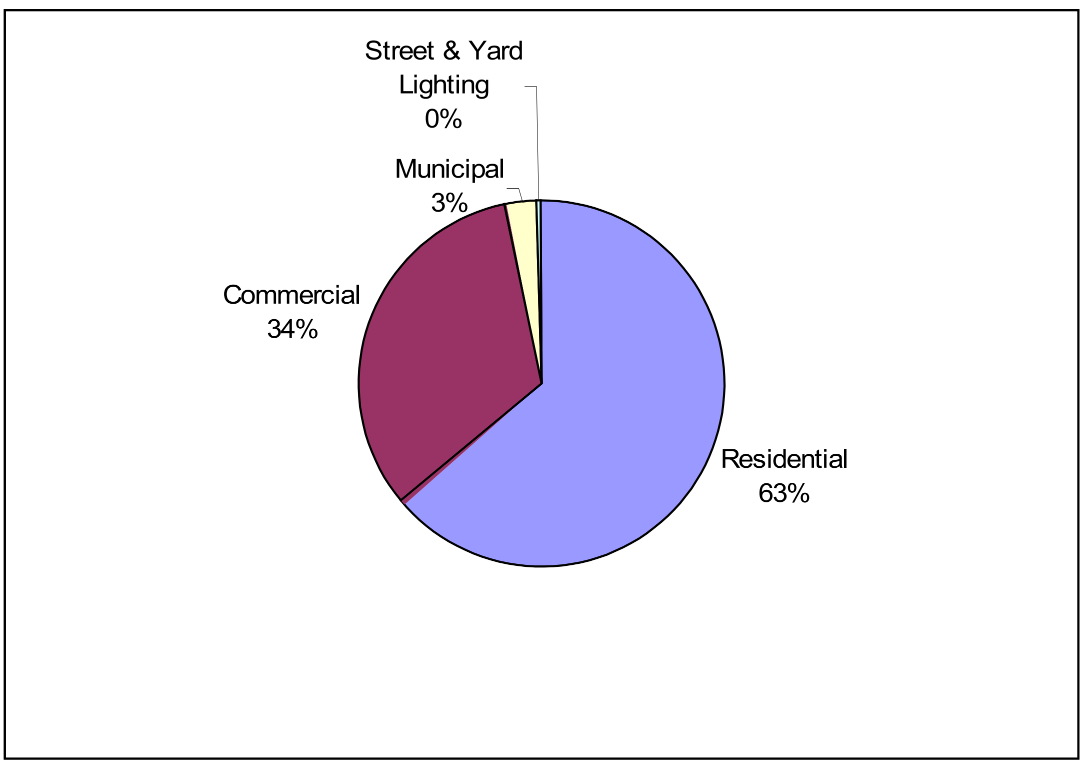
Stow Residential Electric Use (2009)

The chart below illustrates average annual household use by service type. As expected, homes using electric hot water use more electricity and homes with "all electric" service – heating and hot water – use the most.



Average Stow Household Electric Use by Service Type

The chart below shows the breakdown of all electric use in Stow (data courtesy of Hudson Light and Power).



Stow Electric Use by Sector

Nearly two thirds of total electric use in Stow is residential – reflecting our suburban, rural profile. The town of Hudson, on the other hand, has large commercial and industrial users. The profile of electric use in Hudson between the commercial and residential sectors is nearly the reverse of Stow.

Derivation of Stow Home Energy Use by Fuel Mix

The section on home energy use in Stow presented data for both the percentage of homes using different fuels and for the average fuel use. The derivation of this data is from the sources listed below.

1) The number of Stow households using electricity for heating and hot water is taken directly from data provided by Hudson Light and Power.
2) The number of households using natural gas for heating is from the 2000 census data scaled to reflect the increase in the number of households.
3) RECS (Residential Energy Consumption Survey) data for the Northeast was used to determine the number of Stow households that heat with fuel oil also use fuel oil for hot water and the number of household that heat with natural gas and also use natural gas for hot water.
4) Average gas and fuel oil use for hot water is from the RECS (Residential Energy Consumption Survey)

Appendix C: Stow Residential Transportation

Scott Peterson, manager in the Central Transportation Planning Group of the Boston Region Metropolitan Planning Organization generated the estimates for residential transportation in Stow – with a baseline year of 2007. The tables below are courtesy of the Central Transportation Planning Group. Most tables show both Stow and a comparison to the average in eastern Massachusetts:

	2007 VMT By Residents to Anyplace		2007	
Municipality of Residence	Daily Miles Driven by Passenger Vehicles	Annual Miles Driven by Passenger Vehicles	Households	Daily Vehicle Miles Travelled per Household
Stow	179,100	60,894,000	2,088	85.8
Eastern MA Average	85,678,441	29,130,669,910	1,637,023	52.3

Stow Daily Vehicle Miles Traveled

	2007 Productions							
Municipality	Home Based Work Trips	Home Based Personel Business	Home Based Social Recreation	Home Based School	Home Based Pick-up and Dropp-offs	Non-Home Based Work	Non-Home Based Other	Total
Stow	24%	26%	19%	6%	5%	9%	10%	100%
Eastern MA Average	18%	25%	17%	7%	4%	15%	13%	100%

Stow Trips by Trip Type

	2000 Census JTW					
Municipality	Workers	Mean Travel Time	Auto Workers	Mean Travel Time	Transit Workers	Mean Travel Time
Stow	2,930.0	31.2	2,760	29.9	110	71.4
Eastern MA Average	2,078,427	29	1,704,733	27.0	248,124	44.2

Stow Commuters and Mean Travel Time

Traffic Zone	Avg Weekday VMT Occuring Within Stow by all Vehicles (All Person Trips)				
	AM	MD	PM	NT	Total
2201	26,040	44,590	29,470	35,900	136,000
2202	1,100	2,150	1,540	1,770	6,560
2203	14,660	24,800	16,420	19,840	75,720
2204	4,320	6,810	5,440	4,410	20,980
Stow	46,120	78,350	52,870	61,920	239,260

Traffic Zone	Avg Weekday Summer CO2 (kilograms) Occuring Within Stow by Residents of any Community (All Person Trips)					Avg Weekday Summer CO2 (kilograms) Occuring by Residents of Stow to any Destination (All Person Trips)				
	AM	MD	PM	NT	Total	AM	MD	PM	NT	Total
2201	14,490	24,820	16,400	19,980	75,690	10,850	18,580	12,280	14,950	56,660
2202	610	1,200	860	990	3,660	460	900	640	740	2,740
2203	8,160	13,800	9,140	11,040	42,140	6,110	10,330	6,840	8,260	31,540
2204	2,400	3,790	3,030	2,460	11,680	1,800	2,840	2,270	1,840	8,750
Stow	25,660	43,610	29,430	34,470	133,170	19,220	32,650	22,030	25,800	99,700

Stow Daily CO_2 Emissions from Vehicle Trips

The data used to calculate annual CO_2 emission from Stow residential travel is the table in the bottom right above (99,700 kilograms of CO_2 per weekday). Per Scott Peterson, annual vehicle CO_2 emissions are approximately equal to weekday emissions times 340.

Notes

1) A recent study by the EIA (http://www.eia.doe.gov/oiaf/ieo/pdf/0484(2010).pdf) concludes that, in the absence of new national and international regulations, world energy consumption will increase by 49% from 2007 to 2035. The majority of the increase being due to increased demand in developing nations. The study also finds that most of the increase in energy will continue to come from fossil fuels. As a result, it is projected that energy-related CO2 emissions will increase by 43% by 2035.

2) Transitioning away from fossil fuel generation of electricity could, in theory, not be required with proposed technologies to prevent the release of CO2 in the atmosphere. This approach is called CCS (Carbon Capture and Sequestration). The idea is to store the CO2 in geological formations. To date, this approach has not been shown to be viable on a large scale – no commercial generation of electricity from fossil fuel employs it. .

3) For electric vehicles, the EPA calculates mpg (miles per gallon) by comparing the energy content of electricity to gasoline. An electric car that can drive 100 miles using 34 kwh of electricity, equivalent to 116,000 btu. 116,000 btu is the energy content of one gallon of gasoline. The EPA would rate this car at 100 mpg since this is the equivalent energy content of gasoline. The improvement in energy efficiency of electric cars is largely due to the higher efficiency of electric motors as compared to gasoline engines. Gasoline engines are only about 20% efficient while electric motors are around 90% efficient.

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