Town of Belmont CO_2 Emission Inventory Update

Prepared for the Energy Committee

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The Special Town Meeting held in the fall of 2009 voted to adopt a Climate Action Policy committed to reducing greenhouse gas (GHG) emissions in the Town of Belmont by 80% by the year 2050. In furtherance of that commitment, Town Meeting voted also to create the Belmont Energy Committee. The Energy Committee was appointed by the Board of Selectmen in the Spring of 2010. The work of the Energy Committee since 2012 has been devoted to work on electricity, transportation, and residential heating/cooling.

Executive Summary

This update examines how Belmont's CO_2 emissions have changed since the analysis performed for the Town's Climate Action Plan based on emissions in 2007. The major sources of CO_2 emissions considered are transportation (36% of total 2014 emissions), electricity (29%), natural gas (21%), and fuel oil (14%). The sectors considered are residential, non-residential (commercial and institutional), and municipal.

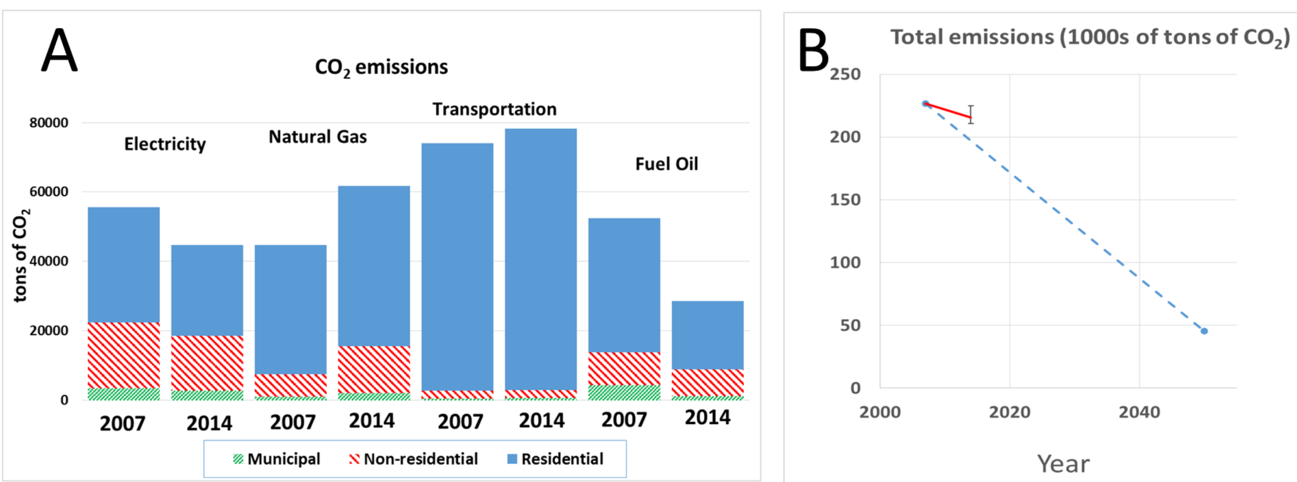
<u>Transportation:</u> Emissions from vehicles (mainly residential) are estimated to have increased by approximately 6% from 2007 to 2014. This was due to a 13% increase in the number of vehicles registered in Belmont; the increase in emissions due to number of vehicles was partially offset by likely improvements in vehicle fuel efficiencies over this time frame.

<u>Electricity:</u> Overall emissions from electricity use declined by 20% from 2007 to 2014. This was due to the decrease in the carbon intensity of the New England grid over this time frame, combined with an unchanged level of electricity consumption in kWh.

<u>Heating fuels (Natural Gas and Fuel Oil):</u> The total emissions from natural gas increased 38% from 2007 to 2014, while those from fuel oil use decreased by approximately 41% in this time period, resulting in a 5% overall decrease in emissions taking the two categories together. This is presumably largely due to conversions from oil to gas heating.

<u>Overall:</u> Total emissions from electricity, transportation, and heating fuels are estimated to have declined by 5% from 2007 to 2014. This is promising, though not as large a decrease as needed to be on track for achieving Belmont's long-term goals. (Figure 1B).

<u>Recommendations:</u> The largest opportunities for reductions lie in the choices made when residents replace vehicles and heating systems. Adoption of electric vehicles and heat pumps offer the potential for substantial reductions.



	CO₂ Emissions (tons)									
	Electricity		Natural Gas		Transportation		Fuel Oil		TOTAL	
	2007	2014	2007	2014	2007	2014	2007	2014	2007	2014
Municipal	3373	2816	1028	2090	379	596	4227	1196	9007	6697
Non-residential	19103	15675	6533	13466	2311	2311	9544	7635	37491	39086
Residential	33113	26144	37092	46265	71408	75387	38696	21980	180309	169776
Unidentified	1019	752								
TOTAL	55589	44635	44653	61820	74098	78294	52467	30811	226808	215560

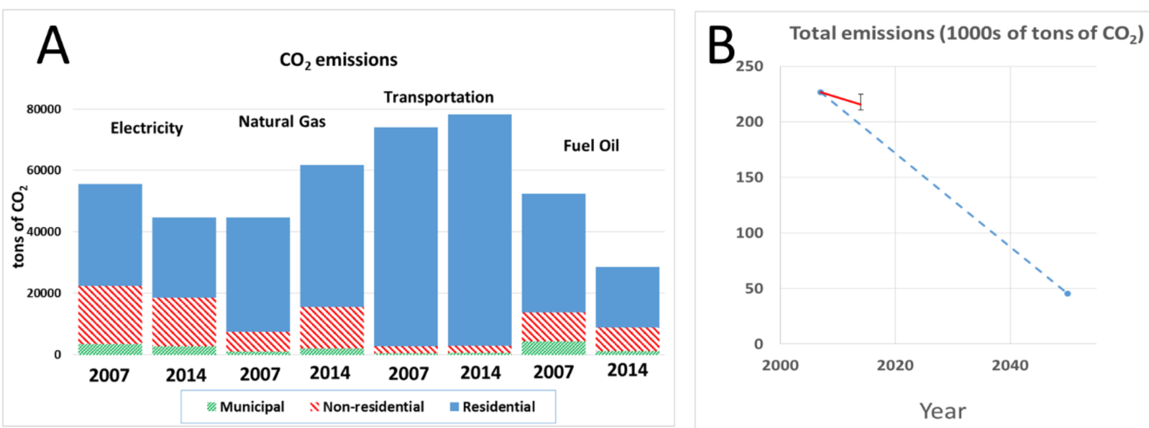
Figure 1. A: Overview of CO_2 emissions. B. Change in emissions from 2007 to 2014, compared to 2050 target. Error bar represents likely range of uncertainty in 2014 estimate.

Overview and Scope

Direct emissions of CO_2 were considered from four sources: electricity, natural gas, heating oil, and vehicular transportation. Emissions were also divided into three sectors: residential (the largest component), municipal and non-residential (which includes both businesses and institutions). Data is reported for 2014, the most recent year for which complete data are available.

Other sources of CO_2 emissions were excluded as being beyond the scope of the analysis both in the CAP and in this update. Of particular note, a major excluded category is emissions associated with air travel by Belmont residents. While the extent of such air travel is challenging to assess, it should be noted that air travel may represent a large fraction of overall emissions for many Belmont households. As a point of comparison, the climate warming potential of emissions associated with a family of four taking a single return trip from Boston to San Francisco by air is equivalent to that from emission of as much as 6 tons of CO_2, more than the entire annual emissions resulting from electricity use by a typical Massachusetts household (2.5 tons of CO_2)[1].

Figure 1A shows a summary of the findings. Figure 1B puts the observed reduction in overall emissions in the context of the long-term reductions needed to reach Belmont's goal of 80% reduction in emissions by 2050.



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Findings and Methodology

Electricity:

Summary: Overall emissions from electricity declined by 20% from 2007 to 2014. This was due to the decrease of carbon intensity of the New England power grid over this time frame, paired with an unchanging level of electricity consumption (in kWh) in Belmont.

There are two factors to consider in determining the total emissions from electricity: total usage in kWh, and the carbon intensity of the electricity used.

For calculating total consumption, billing data were obtained from Belmont Municipal Light Department Annual Reports for the different rate classes[2]. They were combined as follows, as was done in the CAP:

Residential:	Rate A + Low income
Non-residential:	Rate B + Rate E
Municipal:	Municipal B + Municipal E + Street Lighting
Unidentified:	Rate F + Rate G

The overall electricity usage was virtually identical in 2014 to that in 2007 (Table 1)[3]. As shown in Figure 2, in the intervening years electricity usage stayed essentially flat across all sectors. There was a small amount of year-to-year variation (between 1.1 and 2.3 per cent of the total), which may result from annual variation in cooling degree days, with which the fluctuations seen in electricity usage largely correspond (data not shown). While the lack of any reduction in consumption on a kWh basis may seem disappointing, it should be noted that in the CAP it was reported that consumption was increasing at a rate of 1.24 % per year in the period 2001-2007, so stabilization of consumption is at least a step in the right direction.

	2007		2014	
	kWh	tons CO2	kWh	tons CO2
Residential	73177686	33113	72022779	26144
Nonresidential	42216877	19103	43180794	15675
Municipal	7454693	3373	7756491	2816
Unidentified	2251439	1019	2072297	752
TOTAL	125100695	56608	125032361	45387

Table 1. Electricity consumption in kWh and resulting CO2 emissions

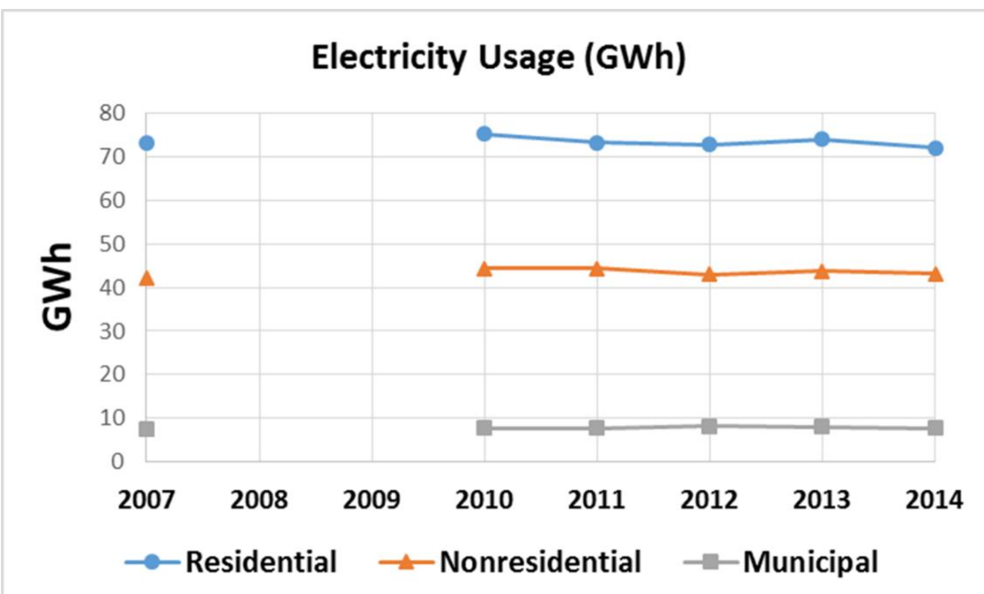

Figure 2. Electricity usage, 2007-2014.

While the total amount of electricity used did not change from 2007 to 2014, the associated CO_2 emissions are nonetheless expected to have declined. From 2007-2014, the carbon intensity (amount of CO_2 emissions per kWh of electricity produced) of the New England grid decreased significantly, largely due to a shift from oil and coal to natural gas for electricity generation. ISO–NE reports system average values for 2007 and 2014 of 905 and 726 lb CO_2/MWh, respectively[4] (Figure 3). These ISO-NE numbers were used to calculate both 2007 and 2014 emissions from the respective kWh consumption data.

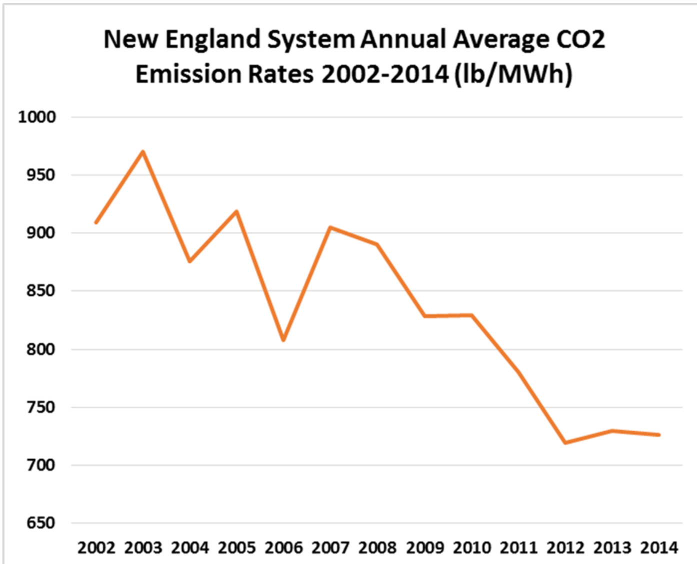

Figure 3. Declining carbon intensity of the New England electric system. Source: 2014 ISO New England Electric Generator Air Emissions Report.
http://www.iso-ne.com/static-assets/documents/2016/01/2014_emissions_report.pdf

We have assumed that the power purchased by Belmont Light reflects the overall carbon intensity of the New England grid. We have also not accounted explicitly for the impact of local generation from renewables; it is small at this time, currently producing electricity equivalent to about 0.3% of the town's total consumption[5].

Transportation:

Summary: Emissions from vehicles (mainly residential) are estimated to have increased approximately 6% from 2007 to 2014. This was due to a 13% increase in the number of vehicles registered in Belmont; the increase in emissions due to number of vehicles was partially offset by likely improvements in vehicle fuel efficiencies over this time frame.

Residential transportation:

There are three factors that determine the direct emissions due to vehicular transportation: number of vehicles, miles driven per vehicle, and vehicle fuel efficiency.

Emissions are calculated as (number of vehicles) × (average miles traveled per vehicle) × (average gallons of gasoline consumed/mile) × (tons of CO_2/gallon of gasoline).

(Note: emissions related to public transit were not considered or included in either the CAP or the update, but are likely small relative to residential vehicular emissions.)

Number of vehicles:

Number in CAP:	15,300 vehicles
Estimate for 2014:	17,300 vehicles

The number of vehicles on the roads of Belmont can be estimated from RMV registration records. The data in Table 2 were obtained from excise tax bills issued for vehicles registered in Belmont.

Number of excise tax bills:								
				Commitment periods				
Tax Year	**1 (Feb)**	**2 (Apr)**	**3 (Jun)**	**4 (Aug)**	**5 (Sept)**	**6 (Dec)**	**7 (Feb)**	**Total**
2015	**17177**	**1001**	**629**	**659**				**19466**
2014	**17309**	**916**	**676**	**715**	**687**	**519**	**458**	**21280**
2013	**17219**	**866**	**749**	**520**	**677**	**469**	**479**	**20979**

Table 2. Auto excise tax bills for 2013-2015 (as of August 2015)

The total number of tax bills issued for 2014 was 21,280. However, this number would be an overestimate of the number of registered cars on the road at any time, because of vehicle turnover. A Belmont resident who sells or trades in an old car and registers a new car within a tax year will be assessed two excise tax bills: one on both the old and the new vehicle. Thus, the total number of bills will include some double counting.

As shown in Table 2, most of the registrations for tax bills are received from RMV for the first commitment period in each year (bills dated in February). The total number of these was essentially constant for the tax years 2013-2015, hovering at around 17,200 vehicles. In light of this, the town Treasurer suggests that the number of bills for the first commitment period likely gives a good estimate of the steady-state number of registered vehicles, with the registrations that arrive during subsequent commitment periods representing mainly newly registered vehicles replacing existing registered vehicles, rather than net addition to the total number[6]. This leads to an estimate for total vehicles for 2014 of 17,300. This is significantly higher than the 15,300 vehicles cited for 2006 in the CAP. Of note, this apparent increase in the total number of vehicles registered in Belmont occurred despite a slight decline in the total population of Belmont from 25,641 in 2006[7] to 24,759 in 2014[8]. The number does appear, however, to have stabilized in recent years, judging from the relatively flat number of tax bills for 2013-2015.

Comparison of the first commitment period bills with the total number of tax bills for 2014 suggests a total turnover of registrations of approximately 20% per year, assuming a fairly constant total number of vehicles in 2013-2015 as suggested by the constant number of total tax bills. This estimate of turnover is consistent with other considerations. Figure 4 shows the number of vehicles with different model years for which 2015 excise tax bills had been received as of Sept. 1, 2015. There are about 1600 vehicles with a model year of 2014, and about the same number for model year 2013. This suggests that purchases or leases of new (current model year) vehicles were around 1600 vehicles/year. Moreover, nationwide sales of used vehicles in this time frame were over 2.5 times higher than new car sales[9], suggesting that the overall number of new registrations (and thus the extent of registration turnover) would be substantially higher than 1600. Nonetheless, it is possible that the total number of vehicles may be somewhat higher than our estimate based on the first commitment period. Of note, there were 827 abatements issued by the Town for 2014 taxes (for taxes paid on vehicles sold, traded, returned to the dealer etc.). This puts an upper limit on the possible number of vehicles of 21,280 – 827 = 20,453 vehicles; in fact, only a fraction of eligible residents request abatements, so the number is almost certainly substantially lower than this.

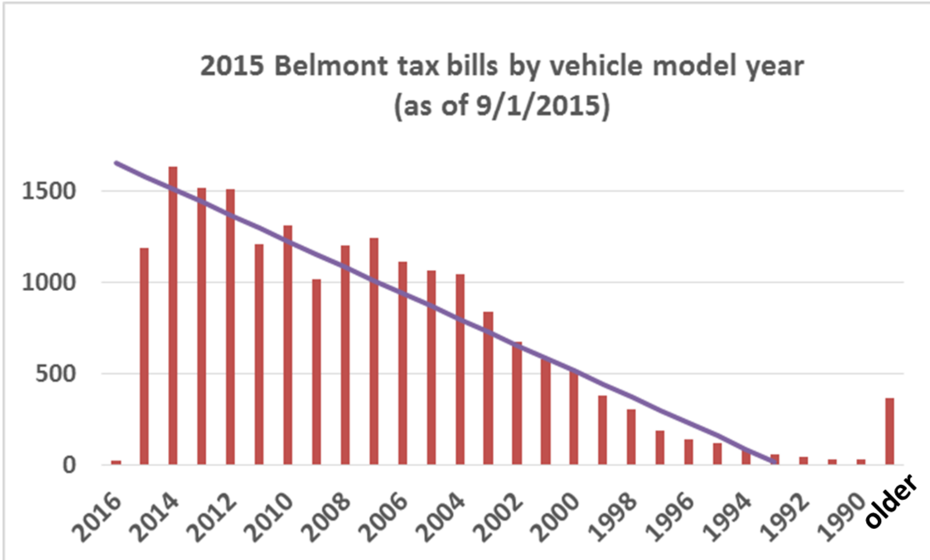

Figure 4. 2015 Belmont excise tax bills by vehicle model year

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<u>Miles driven and Vehicle Efficiency:</u>

For estimating miles driven and vehicle efficiency, data were obtained from the recently assembled Massachusetts Vehicle Census (see Appendix A for more details of the analysis). A random sample was selected of 491 vehicles registered in Belmont that had odometer readings obtained in 2011, the most recent year for which data were available. This gives a snapshot of the Belmont fleet at a point halfway between 2007 and 2014. Based on analysis of this sample, we draw the following conclusions.

Vehicles in Belmont are driven substantially less miles per day on average than the state-wide average (23.2 miles/day for Belmont versus 33 miles/day for Massachusetts) (Figure 5). This lower average vehicle miles traveled is typical of communities located closer to downtown Boston[10].

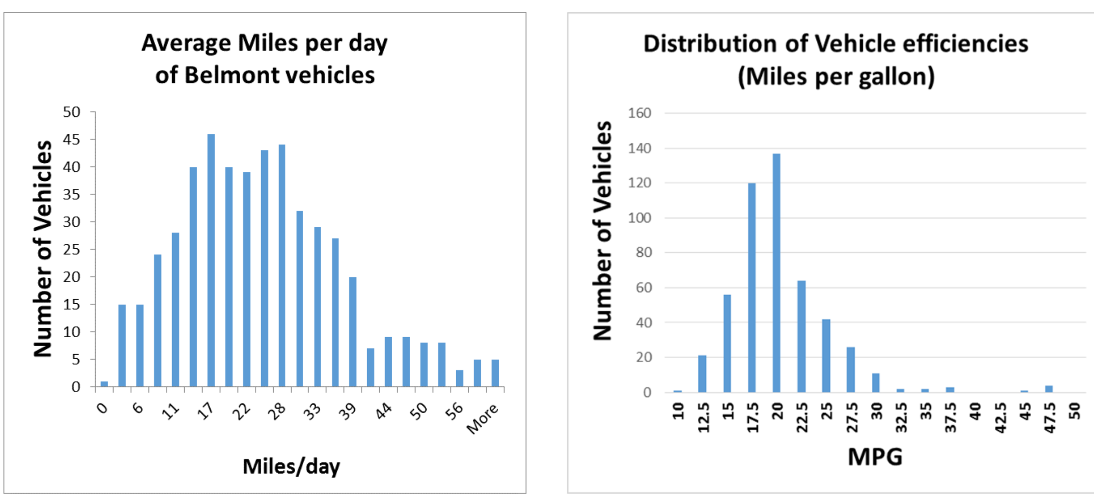


Figure 5. Characteristics of Belmont Vehicles. Distributions of average number of miles driven per day and vehicle efficiency (miles per gallon, adjusted for vehicle age and total mileage).

Overall, vehicles in Belmont in 2011 were slightly more fuel-efficient than the state average. This is largely due to a lower percentage of pick-up trucks in Belmont (such trucks are categorized separately from SUVs in the Vehicle Census, unlike in EPA emissions standards where they both fall under the category of light trucks) (Table 3).

	Belmont	Other MA	
	% of vehicles	% of vehicles	average mpg
Car	65	56	24
SUV	23	23	18
Van	9	8	19
Truck	3	12	16

Table 3. Comparison of mix of vehicle types in Belmont and Massachusetts. EPA mpg averages (not adjusted for vehicle age) are shown for each vehicle type in the Belmont sample.

From the snapshot provided by our sample from the Vehicle Census, we have no data to indicate whether either the miles traveled or the vehicle mix (percentage of cars versus light trucks) changed between 2007 and 2014. Future releases of updates to the Vehicle Census are planned[11]; when these data become available, they should allow these questions to be addressed directly. For the purpose of this update it is *assumed* that both the vehicle miles traveled and the relative proportions of cars and light trucks stayed constant from 2007 to 2014, and are reflected by their 2011 values. This is likely a conservative (i.e. pessimistic) assumption, since in the US as a whole, per capita vehicle miles traveled declined from 2005 through 2013[12].

As for fuel economy, it is likely that there were indeed significant changes from 2006 to 2014. Nationwide, average fuel economy for cars and trucks was largely flat over the period running from 1990-2007 (which would include almost all of the vehicles on the road in 2007). Since 2007, there has been a substantial increase in average fuel economy for both cars (increasing from ~23 mpg in 2007 to ~28 mpg in 2014) and trucks (increasing from ~17 mpg in 2007 to ~20 mpg in 2014) (Figure 6).

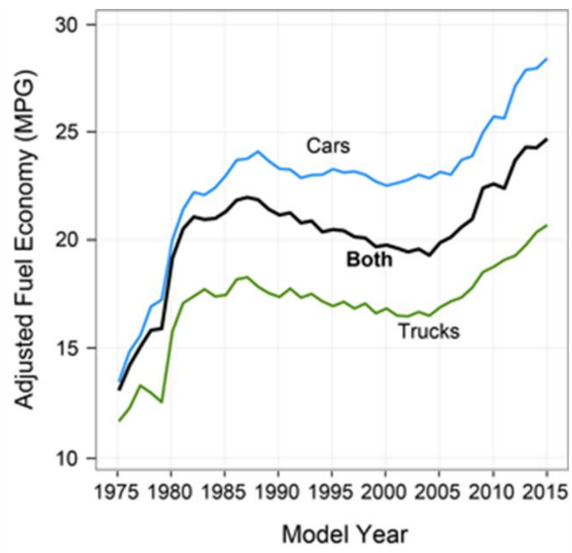


Figure 6. EPA Adjusted Fuel Economy Values for US vehicles. Note: these reflect real-world performance and are on average about 20% lower than unadjusted fuel economy standards values from automakers.
Source: http://www3.epa.gov/otaq/fetrends.htm

The data from our sample given us no reason to think that the fuel economies of cars and light trucks in Belmont differ significantly from those of the overall US fleet within each category. Thus, it is likely that the average fuel efficiency of vehicles in Belmont improved from 2007 to 2014 in parallel with the broader national trends.

To estimate the extent of this effect of increasing fuel efficiency over the time period, we combined the data on car model years from registrations with the annual trends in overall US fuel efficiency. The number of vehicles of a given model year that are registered appears to fall off approximately linearly with increasing vehicle age (Figure 4). We used this to estimate a weighted average of fuel economies for cars in 2014 of approximately 25 mpg. For 2007, we used the average of 23 mpg that was relatively constant over the previous decade. For vehicles other than cars (SUVs, vans, and trucks), we similarly used estimates of 18 mpg for 2007 and 19 mpg for 2014. The overall fuel economy of the Belmont vehicle fleet was determined by weighting by the proportions of cars and non-cars in the vehicle mix (Table 4).[13]

	Cars	Trucks	Cars	Trucks	Overall	Overall
	mpg	mpg	gpm	gpm	gpm	mpg
2007	23	18	0.043	0.056	0.048	21.0
2014	25	19	0.040	0.053	0.044	22.5

Table 4. Estimated average vehicle efficiencies for 2007 and 2014 based on nationwide EPA fuel economy measures and Belmont vehicle mix (65% cars).

These fuel economies are based on those calculated by EPA for new vehicles. The Vehicle Census also includes a further correction factor for the decline in fuel efficiency that occurs with increasing car age and mileage. This factor ranges from 0.67 to 1 for vehicles in our sample, with an average value of 0.87. We assume that the distribution of car ages has stayed similar over time, and thus use this average factor for both 2007 and 2014.

In summary:

Number of vehicles: 2007: 15,600 vehicles registered in Belmont (from CAP)
2014: 17,300 vehicles registered in Belmont (from excise tax records)

Average miles traveled: 23.4 miles/day (assumed constant for both 2007 and 2014)

Corrected miles per gallon: 2007: 21 mpg × 0.87 = 18.3 mpg
2014: 22.5 mpg × 0.87 = 19.6 mpg

Conversion factor: 0.01 ton CO_2 equivalent/gallon of gasoline. (20 lb/gallon)[14]

This conversion factor is for direct emissions from combustion of the gasoline, and was used for both 2007 and 2014. It is worth noting that while the emissions from combustion of a gallon of gasoline do not change over time, the overall CO_2 emissions associated with gasoline *production* (extraction, refining and transport) have been increasing in recent years, as more "tight" oil has entered the market[15]. These production-related emission are significant, amounting to over 35% of the direct tailpipe emissions from combustion in vehicles. This trend toward "dirtier" gasoline will reduce the overall positive climate effects of increasing fuel efficiency, if the indirect emissions associated with production are taken into account.

Overall:

2007: 15,300×23.4×1/(18.3)×0.01×365 = 71,400 tons CO_2

2014: 17,300×23.4×1/(19.6)×0.01×365 = 75,400 tons CO_2

Municipal transportation

Gallons of gasoline and diesel fuel used for municipal vehicles were obtained from MassEnergyInsight, and converted to CO_2 equivalents using the conversion factors 0.01 ton CO_2/gallon of gasoline and 0.011 ton CO_2/gallon of diesel.

Non-residential transportation

In the absence of any information on the small amount of emissions from transportation associated with business and institutions (non-residential), it was simply assumed that it had stayed the same as in 2007.

<u>Heating fuels (Natural Gas and Fuel Oil):</u>

Summary: The total emissions from natural gas increased 38% from 2006 to 2014, while those from fuel oil use decreased by approximately 41% in this time period, resulting in a 5% overall decrease in emissions taking the two categories together. This is presumably largely due to conversions from oil to gas heating.

Natural Gas:

Municipal usage of natural gas in therms was obtained from MassEnergyInsight. Data for overall sales to Belmont were obtained from National Grid; accounts were categorized as Residential and Non-residential. The Non-residential usage for the update was computed by subtracting Municipal usage from total "Non-residential" usage from the National Grid data. A conversion factor of 11.7 lbs of CO_2/therm of natural gas was used (source: US DOE, cited in the CAP).

Heating fuel usage is expected to vary year-to-year depending on the severity of winters. Looking at natural gas usage in the years between 2007 and 2014, there was indeed annual fluctuation that correlated with the number of heating degree days (Figure 7). However, the increasing trend in natural gas use from 2007-2014 is apparent, while there was no such increasing trend in heating degree days over this time frame.

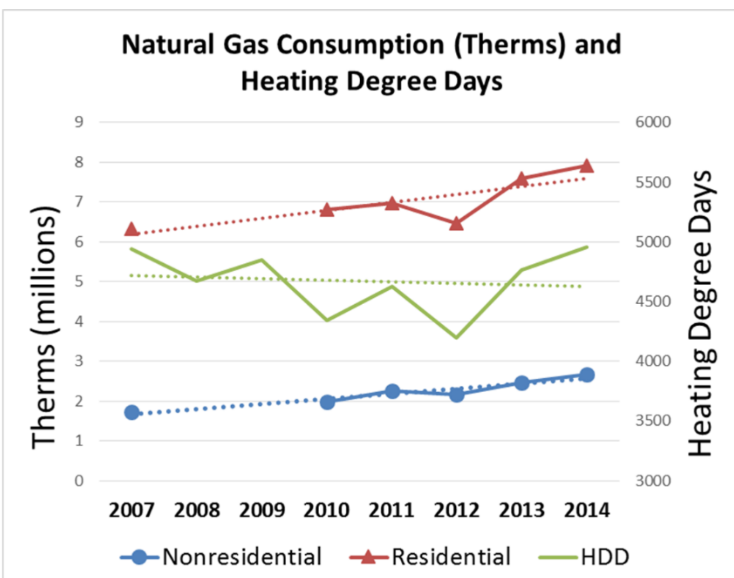


Figure 7. Natural Gas Consumption and Heating Degree Days, 2007-2014.
Note: "Nonresidential" in this figure includes municipal usage.
Source for heating degree days : weatherdatadepot.com, using balance point of 62 degrees.

Heating Oil:

Obtaining estimates of residential fuel oil use is challenging, owing to the multiplicity of fuel oil vendors.

In the CAP, the number of houses heating with oil was estimated at 4392, from census data from 2000 (this was likely an overestimate). Consumption per household was estimated at 716 gallons from the EIA estimate for 2001 for households in New England.

For estimating the number of households in Belmont heating with oil in 2014, census data estimates the number at 2961 for 2013[16], but an estimate from Sagewell puts this number at closer to 2000 households[17]. As for consumption per household, the average consumption for 152 oil-heated homes that received energy audits in 2013-2014 was 785 gallons[18].

Using these estimates, and conversion factors of 1.4969 therms/gallon and 16.4 lbs CO_2/therm (source: DOE, cited in the CAP) gives overall estimated emissions for residential use in 2014 of:

$$\sim 2000 \text{ households} \times \sim 1200 \text{ therms/household} \times 0.00822 \text{ tons } CO_2\text{/therm}$$

$$= 19729 \text{ tons of } CO_2.$$

Municipal usage of fuel oil in gallons was obtained from MassEnergyInsight.

Non-residential fuel oil usage for 2014 is unknown. In the CAP, this was estimated based on conducting a survey of businesses and institutions. Such a survey has not been conducted for this update. For the purpose of this update, it is therefore simply *assumed* that there was a 20% decline in emissions from nonresidential use of fuel oil since 2007. This is likely a relatively conservative guess, given the large reductions in fuel oil use seen in the residential and municipal sectors over the same time frame (49% and 72%, respectively). Also consistent with this estimate is that there were around 60 new non-residential natural gas accounts set up with National Grid over this time period, while in the CAP it was estimated that about half of the town's 566 businesses used oil. If most of the new gas accounts correspond to users switching away from oil, this would represent roughly 20% of businesses.

Overall:

Taken together, the overall emissions from the four sources under consideration declined by ~5% between 2007 and 2014. This is substantial, though not as large as needed to be on track for a target of an 80% reduction by 2050 (Figure 1B).

There are several sources of uncertainty in this estimate, the largest of which are probably the total number of vehicles registered in Belmont and nonresidential fuel oil usage. Taking estimated worst-case and best-case assumptions for each of these (worst case: 19,500 vehicles, 0% decline in nonresidential fuel oil usage since 2007; best case: 17,300 vehicles, 70% decline in nonresidential fuel oil usage) would suggest that the total amount of emissions reduction from 2007 to 2014 very likely lies between 0 and 7% (estimated range shown on in Figure 1B as an error bar on the best-estimate 2014 data point).

Recommendations:

Summary: The largest opportunities for reductions lie in the choices made when replacing vehicles and heating systems. Adoption of electric vehicles and heat pumps offer the potential for significant reductions.

Many actions can help reduce greenhouse gas emissions. Which actions will have the largest potential impacts?

Over the medium to long term, the deep reductions in GHG emissions required to meet Belmont's targets will likely require large-scale shifts to electrification in both the transportation sector (electric cars) and in home heating (heat pumps). This will need to be coupled with a continuing decline in the carbon intensity of the electricity used, through greater incorporation of low- or zero-carbon energy sources, either in the grid at large or through the particular purchasing decisions made by Belmont Light.

The largest opportunities for improvement through the actions of Belmont residents are afforded by the choices made when replacing vehicles and heating systems. In both cases, even relying only on currently available technology, large-scale reductions are possible.

Average vehicle efficiencies will likely continue to improve in coming years as a result of tightening CAFE standards, with a concomitant decline in overall emissions (assuming that the number of vehicles and miles traveled does not also increase, and with the important caveat that indirect emissions from gasoline production are increasing). However, there is a great deal of potential to accelerate this process, if one considers the enormous range of fuel efficiencies of vehicles on the market today (Table 5), and the fact that vehicles are turned over relatively quickly (Figure 3), at least compared to buildings or heating systems. In particular, electric vehicles offer the potential to greatly reduce emissions compared to even relatively efficient internal combustion engine vehicles.

	mpg
BMW550i	20
Toyota Camry	28
Toyota Camry Hybrid	41
Prius Eco	56
Nissan Leaf	114

Table 5. Combined (city/hwy) fuel economy of selected mid-sized cars, 2016. (Note: for the Leaf, an electric car, a conversion factor is used to translate to mpg equivalent (MPGe)). Source: EPA. https://www.fueleconomy.gov/feg/pdfs/guides/FEG2016.pdf

Given the fact that transportation-related emissions are the single largest category of emissions in Belmont, and the very wide range of available vehicle efficiencies, with electric vehicles currently available that produce as little as a fifth of the emissions per mile traveled as the least efficient gasoline vehicles[19], the choice of an efficient vehicle is probably the single most important and effective action most residents of Belmont can take for reducing emissions.

Choosing a home heating system is another juncture at which a large difference can be made, albeit an opportunity that arises less frequently than the choice of a new vehicle. Much of the overall reduction in emissions seen in this update can be attributed to switching of heating systems from oil to natural gas. However, there are a dwindling number of remaining oil-heated homes for potential future reductions from this approach. Moreover, while switching from oil to gas can result in a ~30% reduction in emissions, switching to a heat pump system can lead to as much as a ~60% reduction[20]. Movement from both oil and gas heating to more efficient electric heat pump systems thus has the potential to greatly reduce heating-related emissions. This would improve even further if the carbon intensity of the electricity used continues to decline.

For illustrative purposes, Figure 8 shows the estimated emissions reductions associated with a number of possible actions a household might take[21]. As noted above, fuel switching of vehicles or home heating can result in substantial reductions.

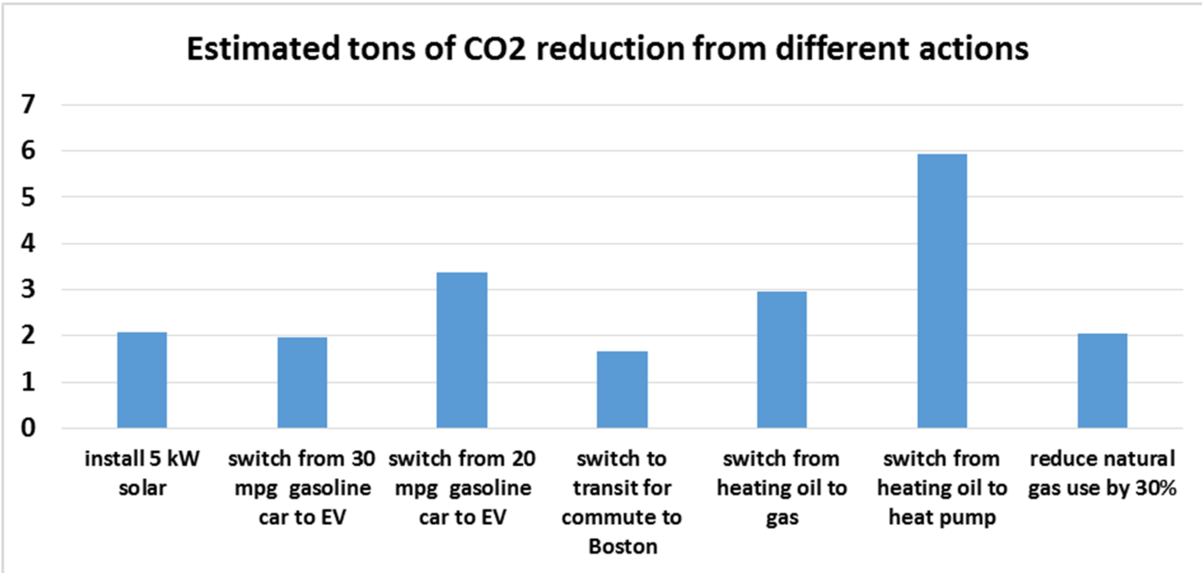


Figure 8. Estimated tons of CO_2 reduction from different actions. See notes for assumptions.

Acknowledgements

I would like to thank Brittany Doherty for obtaining and analyzing municipal energy consumption data from MassEnergyInsight, Terese Hammerle for her investigations of transit usage, Floyd Carman and Maryann Knorr for information related to vehicle excise tax bills, Joanne Bissetta of DoER and Brenda Pike at National Grid for assistance in obtaining natural gas consumption data, and Pasi Miettinen and the members of the Energy Committee for helpful discussion and input.

<u>Appendix A: Analysis of data from the Massachusetts Vehicle Census</u>

<u>Background:</u>

In 2014, the Metropolitan Area Planning Council (MAPC) released the Massachusetts Vehicle Census, a first-in-the nation public database containing data about vehicles in Massachusetts. Drawing from RMV records and information from vehicle inspections, a large amount of information about Massachusetts vehicles, including miles driven, car models, and fuel efficiencies, is available in an anonymized publicly available dataset of 16 million vehicles registered in 2008-2011 that can be downloaded from http://www.37billionmilechallenge.org/.

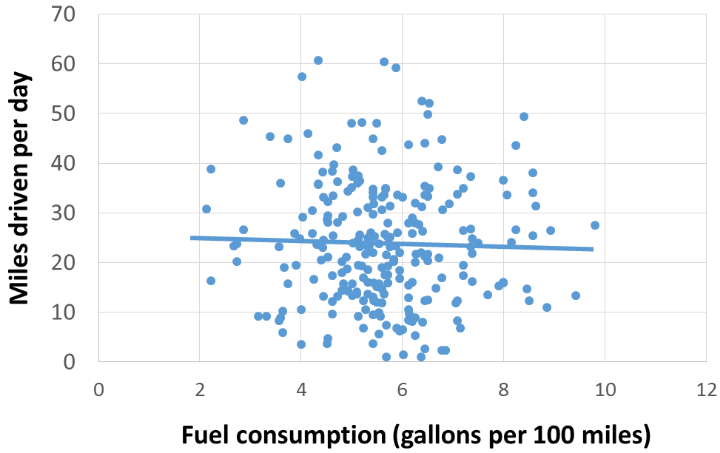
<u>Approach:</u>

While the Vehicle Census is clearly an invaluable resource, its sheer size makes it somewhat cumbersome to work with. I split the 16 million-record database (file: rae_public_noheader.csv) into 160 files each containing 100,000 records. From these, eight files were selected at random (file numbers 58,49,110,61,3,99,86, and 85). These files were then filtered for vehicles registered in Belmont (zip code 02478) that had mileage estimates based on odometer readings from 2011 (the most recent year in the dataset). From this, a sample of 489 Belmont vehicles was obtained. The size of the sample could certainly be further increased if desired by adding data from more files; however, sub-analyses of two samples of 250 vehicles each gave similar overall results, suggesting the sample is large enough to accurately reflect the main characteristics of Belmont's vehicle fleet. For comparison with the statewide vehicle population (miles driven and vehicle mix), a sample of ~34,000 cars with 2011 mileage estimates was drawn from files 49 and 58 (without filtering by zipcode).

A note about why <u>average</u> fuel economy and vehicle miles traveled were used for calculating emissions:

The Vehicle Census includes a computation of CO_2 emissions on a vehicle-by-vehicle basis (i.e. combining mileage and fuel efficiency data <u>for each vehicle separately</u> before averaging). This is presumably a more accurate approach than obtaining population averages for VMT and fuel consumption per mile and then multiplying them together, as we have done. However, using population averages allows us to incorporate estimates of fleet-wide changes in fuel economy that we cannot obtain from the Vehicle Census at this time. For our sample of Belmont vehicles, using average vehicle miles traveled and average fuel efficiencies (found by averaging gallons-per-mile consumption, and *then* taking the reciprocal to get average miles-per-gallon) gives an estimate of 11.8 kg CO_2 per vehicle per day, whereas the vehicle-by-vehicle approach with the same dataset gives a very similar overall average of 11.9 kg CO_2 per vehicle per day.

A situation in which multiplying averages could give incorrect results would be if there is a correlation between vehicle efficiency and miles driven. In particular, one might expect that more efficient vehicles might be driven more miles than less efficient vehicles, either because of the lower cost of driving, or conversely because people who know they have a lot of driving to do might be motivated to buy more efficient vehicles. However, a comparison of vehicle miles traveled with vehicle fuel efficiency in our dataset reveals no strong correlation between these two variables (Appendix Figure 1). The lack of any strong correlation explains why using averages seems to give similar results to a vehicle-by-vehicle approach, and validates the approach based on averages.



Appendix Figure 1: Absence of a strong correlation between miles driven per day and fuel efficiency of vehicle.

Appendix B: Climate Action Plan Resolution

Climate Action Plan Resolution
Belmont Special Town Meeting
November 2009

"WHEREAS, it is acknowledged that there is concern for the productivity and the stability of the Earth's environment, human health, and the global economy related to climate change; and

WHEREAS, the reduction of the use of fossil fuels through conservation and improved efficiency can save money for the Town of Belmont, our community businesses, institutions, and residents;

And

WHEREAS, the increased development of renewable energy sources can lessen our nation's dependence on foreign oil, improve our national security, and spur domestic job creation; and

WHEREAS, the Commonwealth of Massachusetts passed in 2008 the Global Warming Solutions Act committing the state to eighty percent (80%) reduction of greenhouse gas emissions by 2050 and aggressive interim reductions; and

WHEREAS, Sustainable Belmont, on behalf of the Town, has developed a Climate Action Plan for the Town that shows the annual carbon dioxide emissions attributable to Belmont's residents, businesses, institutions, and Town government in 2007 were 277,036 tons of carbon dioxide emissions; and

WHEREAS, the Belmont Climate Action Plan is a working blueprint for the community that addresses the shared responsibility of reducing our carbon dioxide emissions eighty percent (80%) by 2050, therefore be it

RESOLVED, that the Town of Belmont:

ACKNOWLEDGES the concern for the Earth's environment, human health, and the global economy related to climate change;

SUPPORTS the decision of the Board of Selectmen to constitute and appoint an Energy Committee for the Town to review the Belmont Climate Action Plan as a reference document toward the goal of reducing the community's carbon dioxide emissions eighty percent (80%) by 2050 based on 2007 emissions, and for said Committee to provide an annual assessment to the Town through the Board of Selectmen on our community's progress toward achieving said goal; and

ENDORSES the goals of 1) maximizing efficiency within Town operations, purchasing decisions, construction of capital assets, and community planning, through appropriate recognition of energy conservation, 2) promoting efficiency for Town residents, businesses, and institutions, and 3) exploring possibilities for implementing renewable energy use within the Town."

Notes:

[1] Different carbon calculators give a range of values for the climate impact of these flights, ranging from ~3 to ~6 tons of CO_2e, depending on whether the added effects of emissions at high altitude are considered. For comparison with electricity use, we used an average Massachusetts household electricity consumption of 615 kWh per month (https://www.eia.gov/tools/faqs/faq.cfm?id=97&t=3) and 0.35 tons of CO_2 per MWh (see Figure 3).

[2] BMLD Annual Report 2014.

[3] Note: For consistency with the CAP, CO_2 emissions throughout this report are stated in US tons.

[4] 2014 ISO New England Electric Generator Air Emissions Report, Appendix 6. http://www.iso-ne.com/static-assets/documents/2016/01/2014_emissions_report.pdf EPA's Power Profiler gives a similar value of 638 lb/MWh for 2015 emissions. (Note: the value for 2007 emission intensity is significantly lower than the value of 1350 lb CO_2/MWh used in the CAP (source: ICLEI). The reason for the discrepancy is not clear).

[5] Total installed capacity of 306 kWh as of end of 2014 (not counting the Belmont Hill School array). Assuming a capacity factor of 13% (Massachusetts average), this would amount to about 350 MWh per year of generation. Note that under net metering, local generation from solar is implicitly accounted for as a reduction in overall consumption.

[6] Personal communication, Floyd Carman.

[7] Cited in CAP.

[8] Source: http://www.bestplaces.net/people/city/massachusetts/belmont

[9] Manheim 2015 Used Car Report.

[10] "Vehicle Miles Traveled in Massachusetts: Who is Driving and Where are they Going?" Presentation by Timothy Reardon, Metropolitan Area Planning Council. Available at http://willbrownsberger.com/wp-content/uploads/2010/04/MAPC_Reardon_Climate-Change-Committee-4_13_10.pdf

[11] Personal communication, Timothy Reardon, MAPC.

[12] http://www.ssti.us/2014/02/vmt-drops-ninth-year-dots-taking-notice/

[13] Note that averaging was done by first averaging consumption in gallons per mile, then taking the reciprocal of the average to find the average miles per gallon. Since the final multiplication is of miles traveled times gallons per mile, this is preferable to averaging the miles-per-gallon figures.

[14] Source: Terrapass (www.terrapass.com)

[15] Union of Concerned Scientists. *Fueling a Clean Transportation Future – Smart Fuel Choices for a Warming World* (2016)

[16] www.census.gov

[17] Personal communication, Pasi Miettinen, Sagewell.

[18] IBID

[19] The Union of Concerned Scientists estimates that a 2016 Nissan Leaf (24 kWh) charged in Belmont would produce GHG emissions equivalent to a gasoline car getting 96 miles per gallon. http://www.ucsusa.org/clean-vehicles/electric-vehicles/ev-emissions-tool

[20]Source: Northeast Energy Efficiency Partnerships, *North-East/Mid-Atlantic Air-Source Heat Pump Market Strategies Report*, p. 24, which states that 6200 kWh of heat pump use would displace 507 gallons of oil use, assuming an annual coefficient of performance of 2.5. This gives a conversion factor of 12.23 kWh of electricity use per gallon of oil displaced, which implies a 64% reduction in CO_2 emissions.

[21] Assumptions used in estimating emissions reductions from different actions in Figure 8:
Solar: Capacity factor of 13% (average for MA); assume solar generation displaces electricity otherwise derived from the New England grid mix. Assume SRECs are retained by household, not sold.
Switch to EV: Assume average 23.4 miles/day driving. Assume switching to Nissan Leaf with emissions equivalent to 96 mpg gasoline car, compared to vehicles with indicated mpg.
Transit: For commuting from Belmont Center to the Massachusetts State House, 5 days a week, 48 weeks a year, in a 25 mpg vehicle. Treat emissions associated with transit use as negligible.
Heating fuel switching: Assume 800 gallons/year oil use, 30% GHG savings from switching to gas, 60% from switching to heat pump.
For natural gas: Assume 30% reduction from baseline of current average use by 100 houses in Belmont with average size 2452 sq. ft. (from “Neighbor comparison” section of a National Grid bill)