CAMBRIDGE, MA

BUILDING ENERGY PRIMER

Prepared for

the Cambridge Getting to Net Zero Task Force

By Peregrine Energy Group

August 4, 2014

PEREGRINE ENERGY GROUP

Table of Contents

Executive Summary i

Introduction...1

Cambridge Background and Population 1

Building Energy Use and CO_2 Emissions 2

Energy Use...2

CO_2 Emissions from Building Energy Use 3

On-Site Electric Generation...6

Cambridge Building Stock...7

Residential Buildings 7

Commercial Buildings...8

University Buildings...10

Energy Use by Building Type 10

Conclusion 12

References...13

Executive Summary

The Cambridge Getting to Net Zero Task Force is charged with advancing the goal of making Cambridge a "net zero community," with a focus on reducing carbon emissions from building operations. This Building Energy Primer is intended to support the Task Force by providing information about population trends, building energy use, and CO_2 emissions in Cambridge and the city's building stock.

Population

- With a population of more than 105,000, Cambridge is the fifth-largest city in Massachusetts after Boston, Worcester, Springfield, and Lowell.
- After dropping from 1950 to 1980, the city's population has been increasing since the 1980s and is projected to increase through 2030.

Building Energy Use and CO_2 Emissions

- Consumption of electricity and natural gas in Cambridge has been nearly flat over the last decade.
- Natural gas is the primary energy source used in the city, accounting for 54% of total energy consumption, followed by grid electricity at 40%.
- Although second to natural gas in consumption, grid electricity is the largest contributor to carbon emissions because of its higher carbon intensity.
- Cambridge is home to 130 on-site electricity generators, which together produce more than 11% of the electricity consumed in the city.

Cambridge Building Stock

- Buildings in Cambridge fall into three major groupings: residential, commercial, and university.
- Approximately 60% of housing units are occupied by tenants and 27% are condominiums. Rental housing and condominiums present challenges for energy efficiency initiatives because of landlord-tenant split incentives and other barriers.
- Within commercial space, office space accounts for the highest percentage of building square footage, followed by labs, retail space, and hotels.
- University buildings account for 25% of total building square footage in the city.

Energy Use by Building Type

- No single building type contributes more than 21% of the total. Major contributors to energy use include commercial labs, office space, large residential buildings, and university labs.

Introduction

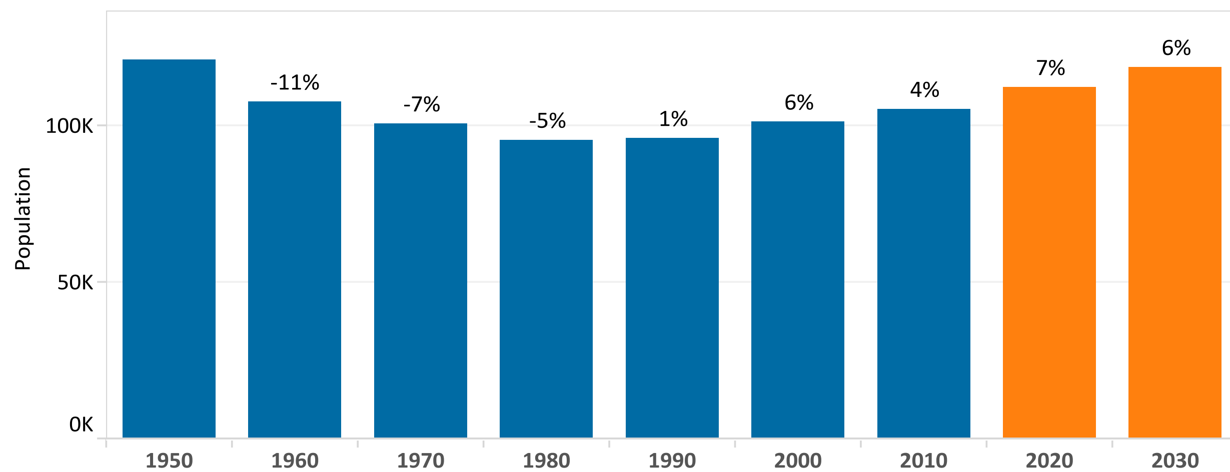
In December 2013, the City of Cambridge created the Getting to Net Zero Task Force. The Task Force was charged with advancing the goal of making Cambridge a “net zero community,” with a focus on reducing carbon emissions from building operations. Achieving this goal will require reducing the energy use intensity of buildings and taking advantage of opportunities to harvest energy from renewable sources. This Building Energy Primer is intended to support the Task Force by providing information about population trends, building energy use, and CO_2 emissions in Cambridge and the city’s building stock.

Cambridge Background and Population

With a population of more than 105,000, Cambridge is the fifth-largest city in Massachusetts after Boston, Worcester, Springfield, and Lowell. Remarkable for its world-leading universities, burgeoning biotech businesses, stately neighborhoods, and diverse population, Cambridge is one of the most vibrant cities in the Northeast.

After dropping from 1950 to 1980, the population of Cambridge has been increasing since the 1980s and is projected to increase through 2030.

Population 1950 - 2030



Figures beyond 2010 are projections. Sources: CDD 2011; MAPC

The median age of Cambridge residents is 30.2, with more than half of the residents between 20 and 39 years of age. College students make up another significant fraction of the population; 15% of city residents live in college dormitories (CDD 2011).

Building Energy Use and CO_2 Emissions

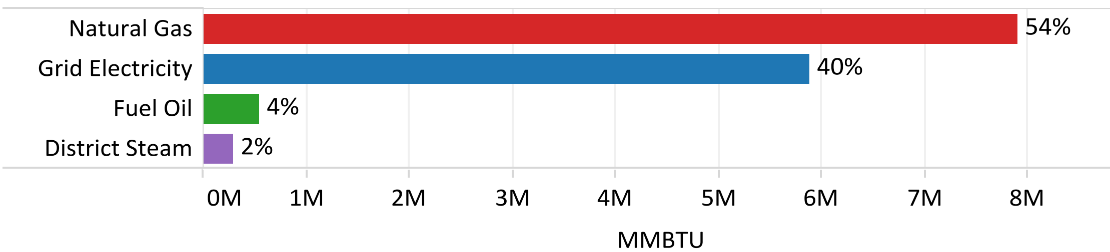
Energy Use

Buildings in Cambridge use energy from several sources:

- Natural gas
- Electricity from the regional electric grid ("grid electricity")
- Electricity generated at customer sites within Cambridge ("on-site electricity" - examples include large generating plants at the universities and solar PV facilities throughout the city)
- Heating oil
- Steam from the Veolia steam distribution network

Natural gas is the primary energy source used in Cambridge, accounting for 54% of total energy consumption,[1] followed by grid electricity at 40%.

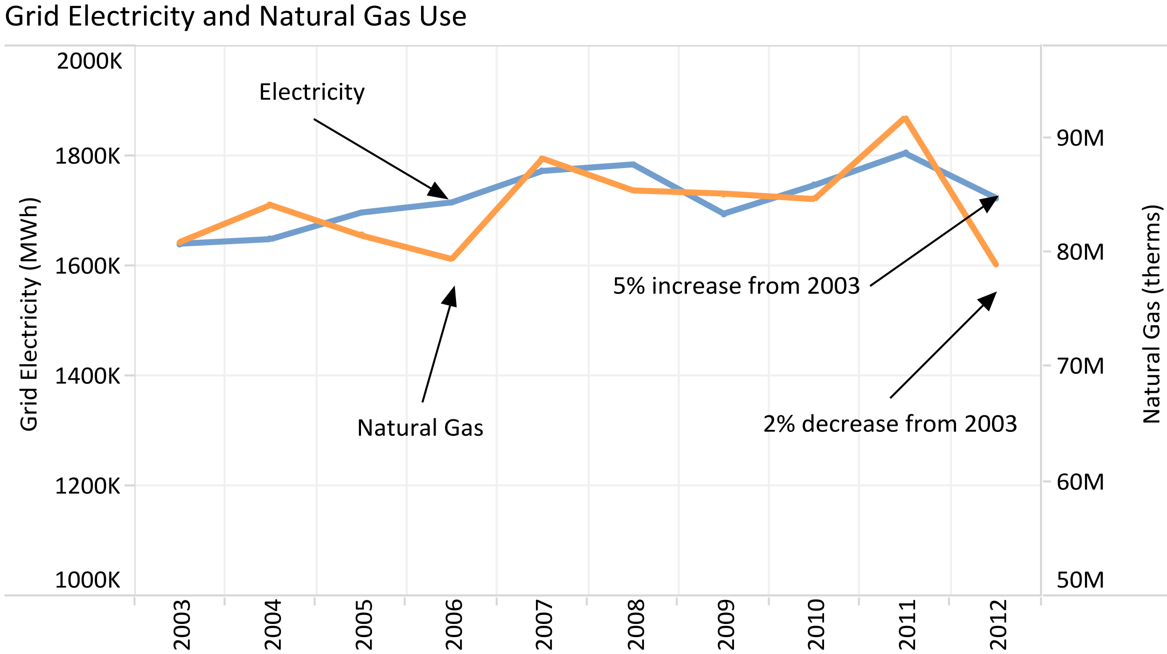
Energy Use (MMBTU) by Fuel 2012



Sources: Natural gas and grid electricity reported by NSTAR; fuel oil estimated from US census, EIA, and CAD 2012; district steam reported by Veolia

For the major fuels, which are natural gas and grid electricity, use in Cambridge has been nearly flat over the last decade. While use has fluctuated from year to year due to variations in weather and economic activity, grid electricity use has increased just 5% and gas use has declined 3% over the decade, according to data provided by NSTAR.

[1] The natural gas total includes both the gas used directly in buildings and also natural gas burned to generate electricity with on-site generators. The city does not have the data necessary to break out these categories of gas use. To avoid double counting, on-site electric generation is not reported in the energy use and CO_2 emission totals because that use and emissions are included in the natural gas figures.



Source: NSTAR

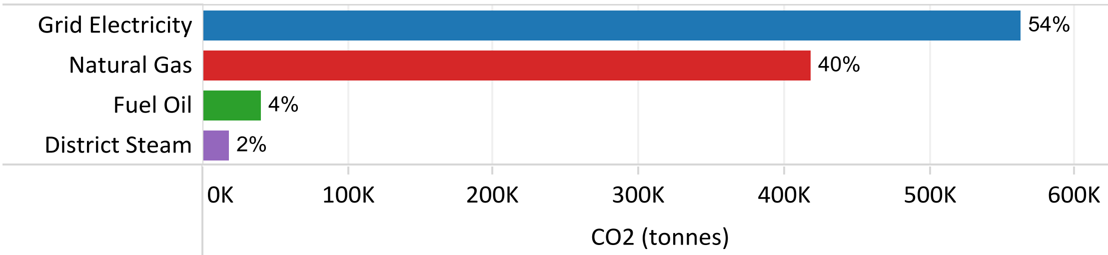
The use trend in Cambridge is similar to that for the state as a whole. According to data from the Energy Information Administration, both electricity and natural gas use in Massachusetts were virtually the same in 2012 as they were in 2003 (EIA 2014a and 2014b).

The Cambridge experience is also consistent with national trends. While until recently it was possible to count on annual growth in electricity consumption of 1% to 2% per year, electricity use nationally is lower now than it was in 2007. The recession certainly played a part in this decline, but analysts also see a significant contribution from increases in energy efficiency (Nadel).

CO_2 Emissions from Building Energy Use

Energy use in buildings results in carbon emissions, either as a result of burning the fuel at the customer site (as is the case for natural gas and fuel oil used on site) or burning fuel at a central plant to generate electricity or district steam that is then delivered to and consumed by the customer. The carbon emissions from building energy use in Cambridge are shown in the figure below.

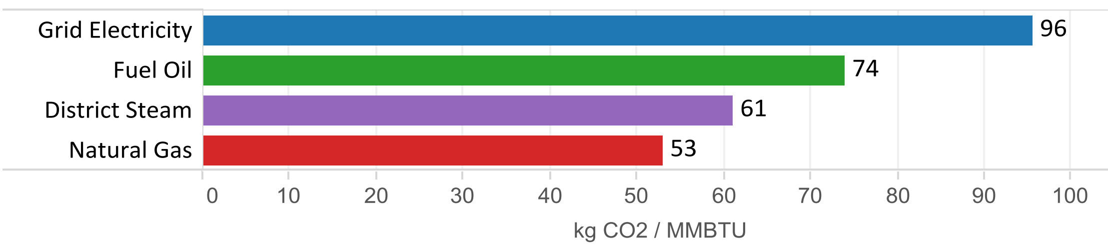
CO2 Emissions by Fuel 2012



Emissions are calculated by multiplying energy use by emission factors. Sources for emission factors: ISO New England 2014a (electricity); The Climate Registry (natural gas and fuel oil); Veolia (district steam)[2]

Whereas natural gas is the largest contributor to energy use in the City, grid electricity is the largest contributor to CO_2 emissions. The different fuels have different carbon intensities, that is, different levels of carbon emissions per unit of fuel consumed by the customer. As is shown in the chart below, grid electricity has the highest carbon intensity of the fuels used in Cambridge, and natural gas has the lowest.

CO2 Emissions per MMBTU

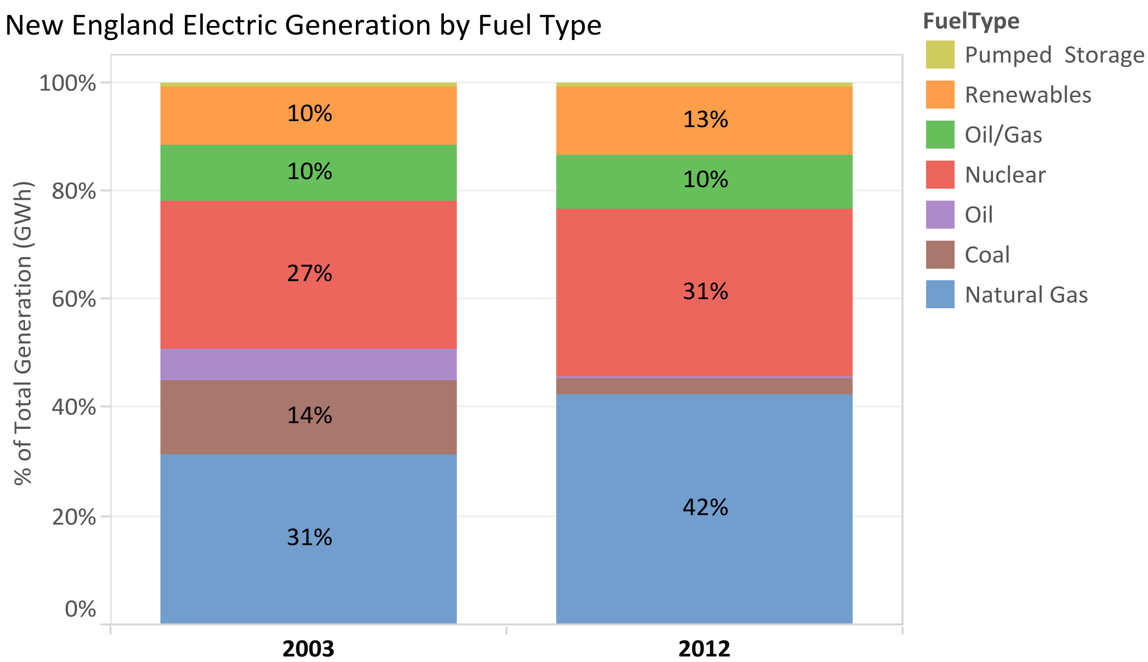


Sources: ISO New England 2014a (electricity); The Climate Registry (natural gas and oil); Veolia (district steam)

These emission factors are constant for natural gas and heating oil. However, they vary for electricity as the mix of fuels used to generate electricity can vary from year to year. The same is true for district steam.

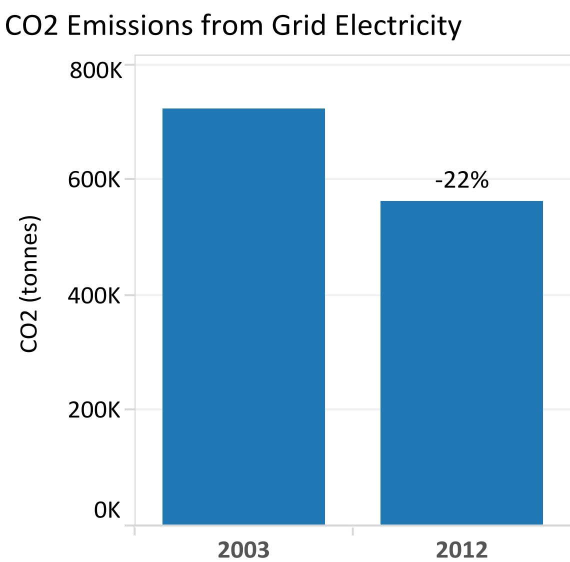
Although grid electricity remains the most carbon-intensive fuel consumed in Cambridge, the carbon intensity of grid electricity in New England has declined substantially over the last decade. Largely for economic reasons, the region has been making greater use of new power plants that burn natural gas (a lower-carbon fuel) and moving away from (and in some cases closing) older plants that burn coal and oil (higher-carbon fuels). Coal- and oil-fired plants accounted for 20% of electric generation in 2003 but just 3% today. The chart below shows the New England electric generation mix by fuel in 2003 and 2012.

[2] The district steam emission factor is will be modified based on the most recent guidance issued by the Department of Energy Resources.



Source: ISO New England 2014b

As a result of this improvement in the carbon performance of the electric grid, Cambridge's CO_2 emissions from grid electricity dropped by 22% from 2003 to 2012, even though use of electricity rose slightly during that period.



While the region's greenhouse gas footprint has benefitted from this trend, unfortunately it is unlikely to continue. With coal and oil use for electric generation down to near zero, New England has little potential for additional emissions improvement from switching from coal and oil to natural gas.

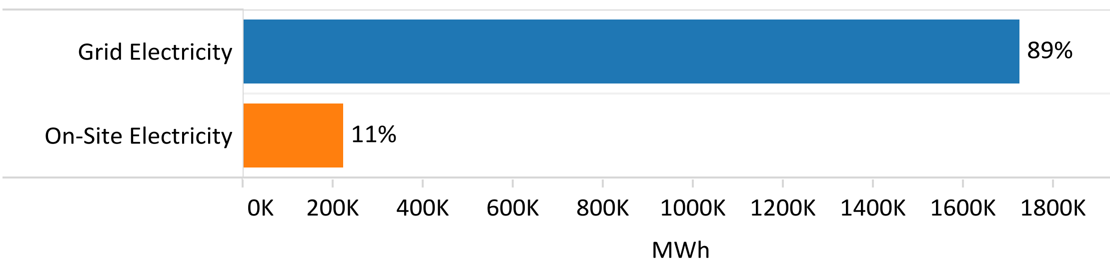
Further improvements in the carbon intensity of grid electricity will likely need to come from increasing the percentage of electricity generated by renewables. As shown in the earlier chart, entitled New England Generation by Fuel Type, renewable generation increased by one-third from 2003 to 2012 but still makes up just 13% of the total.

On-Site Electric Generation

Cambridge is home to 130 on-site electricity generators, which together produce more than 11% of the electricity consumed in the city. The great bulk of the electric generation comes from a handful of gas-fired cogeneration systems owned by the universities and large businesses. These cogeneration systems produce both electricity and steam, with the steam used for heating and industrial processes.

Over the last several years, Cambridge residents and businesses have also installed more than 100 solar PV systems. Although small individually, and still modest even in aggregate (just 1% of total on-site generation), these systems represent a growing part of the City's energy future.

Grid and On-Site Electric Generation 2012



Sources: grid electricity reported by NSTAR; on-site electricity from NSTAR Electric 2006 – 2012 and reports from system owners

On-site Electric Generation 2012

Fuel Type	Generation (MWh)	Generation %	Capacity (MW)	Projects
Natural gas	219,610	99%	33.9	13
Solar	1,557	1%	1.3	111
Biodiesel	200	<1%	0.1	1
Wind	35	<1%	<0.1	5
Grand Total	**221,401**	**100%**	**35.3**	**130**

Sources: NSTAR Electric 2006 – 2012 and reports from system owners

Cambridge Building Stock

Buildings in Cambridge fall into three major groupings: residential, commercial, and university.

Residential Buildings

Residential housing units in Cambridge fall nearly evenly into three buckets: 1 – 3 unit homes, small, multi-family buildings of 4 – 50 units, and large, multifamily buildings of 51 units and above.

Residential Housing Stock 2010

Housing Type	Properties	Units	% of Total Units	% of Units that are Condominiums
1 – 3 family	9,361	17,088	35%	19%
4 – 50 units	1,615	15,024	30%	40%
51 + units	132	17,418	35%	23%
Grand total	**11,108**	**49,530**	**100%**	**27%**

Source: CDD 2011

While the number of units is roughly evenly divided among the groups, it is also important to look at the number of buildings in each group. While the units in one-to-three family homes are spread over more than 9,000 buildings, the same number of units can be found in just 132 large, multifamily buildings. When deploying energy efficiency strategies, it may be more effective to concentrate on the small number of buildings with the greatest number of units, rather than on the thousands of buildings with just one to three units.

The Cambridge building stock is largely mature. The City added approximately 6,000 residential housing units from 2001 to 2013, a growth rate of approximately 1% per year. With the downturn in the economy, housing starts dropped off considerably from 2008 through 2011. However, starts have rebounded in 2012 (1.8% growth) and 2013 (3.6% growth).[3] But even with this upturn, the City will need to look for efficiency gains within its existing buildings rather than relying on highly efficient new buildings to make a big contribution to overall emission reductions.

Cambridge is a city of renters, with approximately 60% of housing units occupied by tenants (CDD 2011). It also has a high percentage of condominiums, 27% of total housing units.

These two facts create challenges for energy efficiency delivery. The rental units present a classic market barrier known as the “landlord-tenant split incentive.” This barrier has been explained as follows:

[3] Housing starts data from Cambridge Community Development Department.

> The split incentive is a particularly pernicious market failure that plagues any number of energy improvement programs. Put simply, a "split incentive" market failure is said to exist when benefits of a transaction pass to someone other than the party paying the cost. In [multifamily buildings], the split incentive manifests itself when tenants pay the utility bills (directly or indirectly) but have no control over capital investments that affect energy consumption. Those few investments that a tenant might make that could impact their utility bill tend not to be completed, as the tenant will be unable to take the improvement with them when they move. (Hynek)

Condominiums present a related set of problems. As discussed by the MIT Energy Strategy Project:

> Even in cases where multifamily housing residents own their own units [as in a condominium], they typically do not have full control over their energy consumption. Often, a homeowner association or coop board must agree to any structural improvements in individually owned units, and these institutions often act as impediments to energy efficiency programs. Furthermore, multifamily buildings typically share a single heating system, and an individual owner-resident is unable to take action to improve it without the consent of other building stakeholders. (Cook)

For these reasons, many traditional energy efficiency delivery mechanisms often have less success in rental housing and condominiums than they do in traditional, owner-occupied, single-family homes. Given the high percentage of these challenging residential space types in Cambridge, the City may need to look for or develop innovative delivery approaches to achieve aggressive goals for residential energy efficiency.

Commercial Buildings

Unlike its neighbor, Boston, Cambridge does not have a downtown of large office towers. Instead, Cambridge is a city of small- and mid-rise commercial buildings. Twenty-two percent of the commercial space is in buildings of one and two stories. Buildings of seven stories and higher account for just under one-third of the total square footage and less that 6% of the total number of buildings.

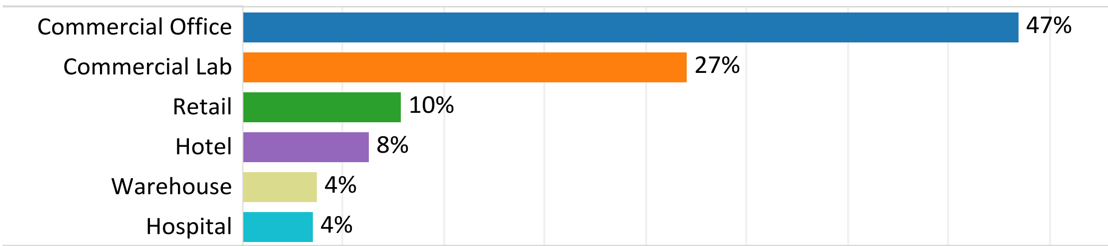
Commercial Square Footage by Building Height

Stories	Percent of Commercial Square Footage	Number of Buildings
1 – 2	22%	700
3 – 4	20%	180
5 – 6	22%	90
7 and above	31%	60

Source: CPD

Looking at commercial buildings by space type, commercial office space accounts for the highest percentage of the square footage, followed by labs, retail space, and hotels.

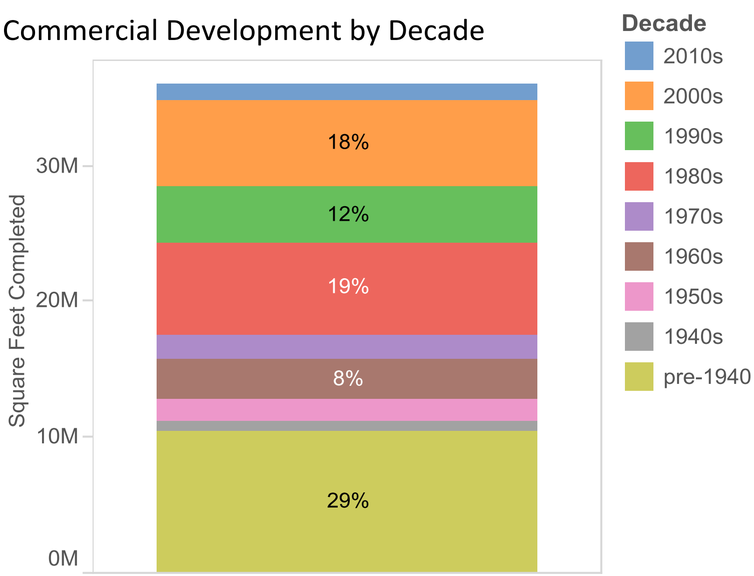
Commercial Square Footage



Source: CPD

Cambridge certainly has a large complement of old office buildings; 29% of the commercial square footage was built before 1940. However, Cambridge has also been adding new commercial buildings much more rapidly than residential buildings. Approximately half of the commercial space in the city has been built since 1980, with rapid development since 2000. Many of these new buildings are in the Kendall Square area and house the City's burgeoning biotech business sector.

Commercial Development by Decade



Source: CDD 2011

As is the case in the residential sector, the City's commercial space presents challenges for energy efficiency delivery. First, a high percentage of commercial space is leased, and so commercial buildings are faced with the same landlord-tenant split incentive discussed in connection with residential buildings. Also, the very small commercial buildings that are so prevalent in Cambridge can be difficult to target for efficiency reductions because they often do not use enough energy to present an attractive business opportunity for an energy efficiency company. The commercial lab space presents the opposite challenge. Labs tend to be highly energy intensive. However, their energy uses are both sophisticated and demanding, requiring a high level of expertise to find and implement energy efficiency opportunities. Accordingly, labs are not good candidates for cookie-cutter energy efficiency program delivery and may instead require custom programs tailored to specific conditions. As with the residential sector, Cambridge may need to find innovative models to achieve large gains in efficiency in its commercial buildings.

University Buildings

Perhaps the most remarkable feature of the Cambridge building stock is the high percentage of university buildings. Home to Harvard, MIT, Lesley University and Cambridge College, university buildings account for 25% of the city's total (CPD).[4]

Higher Education Square Footage

The high percentage of university buildings is likely a plus for Cambridge's efforts to achieve significant gains in energy efficiency. Universities are natural leaders in efficiency given their public missions and long-term ownership of their buildings. Universities are often willing to invest in longer-term payback efficiency measures because they know they will own the buildings long enough to realize the savings from the investments. Unlike most businesses, the universities know that they won't be closing or moving any time soon. Harvard and MIT are both implementing ambitious sustainability initiatives. Harvard has adopted a goal of reducing greenhouse gas emissions by 30% by 2016, including growth, from a 2006 baseline, and has achieved reduction of 21% (with growth) through fiscal 2013 (Harvard University). MIT's Efficiency Forward initiative was the first multi-year energy efficiency agreement between a major customer and a Massachusetts utility and created a template that has been replicated across the state. The universities will be strong partners for Cambridge as it works to improve energy efficiency across the city.

Energy Use by Building Type

A plan to improve energy efficiency in buildings should be informed by information about energy use by building sector and building type. The City needs to know which types of buildings present the greatest opportunities and where to focus its efforts.

[4] This figure includes only university-owned educational buildings. It does not include the commercial buildings owned by the universities, which is categorized with the other commercial space.

Unfortunately, while the Task Force has access to aggregate data about energy use in the city has a whole, it does not have access data broken out by customer or space type. Absent a building disclosure ordinance, customer-level energy use data is confidential, and utilities and other energy suppliers do not report (or necessarily even track) energy use by building type. As Cambridge implements its Building Use Disclosure Ordinance, detailed information will become available in the future, but that information is not available today.

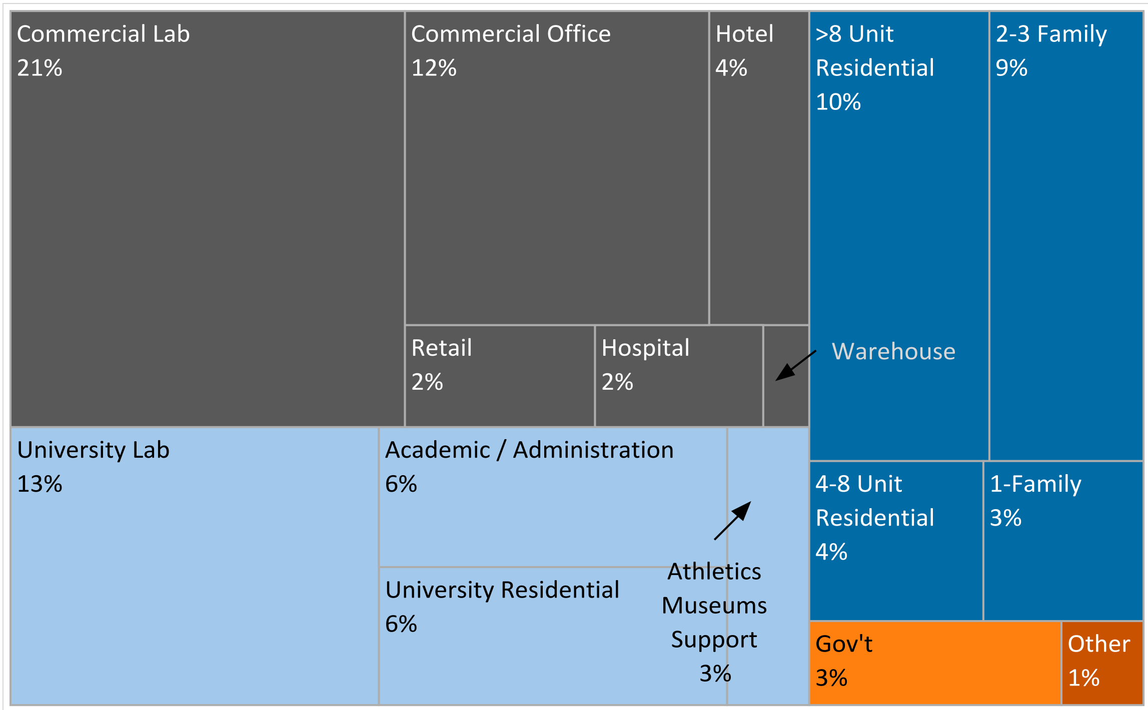
Accordingly, we estimated energy use by building sector and type using a) building square footage data from the Cambridge Property Database and b) estimates of energy use intensity (use per square foot) by building type. Some building types are more energy intensive than others. For example, hospitals are more energy intensive than warehouses; labs are more energy intensive than retails stores; multifamily buildings are more energy intensive that single-family. By applying the energy use intensity for a space type to the square footage, we can estimate the total energy use of the buildings of that space type.

It is important to recognize that having a high energy use intensity does not mean that a space type is “bad” or “wasteful.” Some of the most socially valuable space types (hospitals and labs) have the highest energy use intensities. A high energy use intensity simply tells us that a space type is using a lot of energy per square foot; it does not tell us that the space type is using “too much.”

The figures that result from the analysis are simply estimates; they are not reports of actual usage. The estimates are offered simply as high-level guidance regarding where energy use is concentrated in Cambridge.

The results show that several building types make significant contributions to energy use in the City. No single building type contributes more than 21% of the total. Major contributors to energy use include commercial labs, office space, large residential buildings, and university labs.

Estimated Energy Use by Space Type



Conclusion

The Getting to Net Zero Task Force has a challenging mission. While the city's energy use has been flat for the last decade (despite growth) and carbon emissions have declined (due to fuel switching in electricity generation), there is no easy path from here to net zero. Several characteristics of the city make it harder to improve energy efficiency in Cambridge than in other places: the great majority of the buildings are small, old, and unlikely to be replaced; most of the housing units are rentals and many of the others are condominiums; and much of the non-residential energy use takes place in labs – highly energy-intensive spaces with critical demands for energy that often require sophisticated engineering to improve energy efficiency. On the other hand, Cambridge has advantages. The population is informed and engaged and fully 25% of the city's building stock is owned by universities, natural partners in an aggressive energy efficiency initiative.

References

CDD (Cambridge Community Development Department). 2013. *City of Cambridge Massachusetts: Neighborhood Statistical Profile.* Cambridge, MA.

________. 2011. *City* of *Cambridge Massachusetts: Statistical Profile.* Cambridge, MA.

CAD (Cambridge Assessing Department) 2012. *Property Database*. Cambridge, MA.

The Climate Registry. 2013. *The Climate Registry's 2013 Default Emission Factors*. Los Angeles, CA.

Cook, R. 2013. Empowering *Communities to Overcome Barriers to Multifamily Energy Efficiency*. MIT Department of Urban Studies and Planning, MIT Energy Efficiency Strategy Project, Cambridge, MA.

EIA (U.S. Energy Information Administration). 2014a. *Massachusetts Electricity Profile 2012.* Washington, DC.

______. 2014b. *Massachusetts Natural Gas Consumption by End Use.* Washington, DC. 2014.

Harvard University. 2013. *Sustainability Progress Report 2013*. Cambridge, MA.

Hynek, D., M. Levy, and B. Smith. 2012. *"Follow the Money": Overcoming the Split Incentive for Effective Energy Efficiency Program Design in Multi-family Buildings.* American Council for an Energy Efficient Economy Summer Study on Energy Efficiency in Buildings, Washington, DC.

ISO New England. 2014a. *Electric Generator Air Emissions Report (2012)*. Holyoke, MA.

______. 2014b. *Net Energy and Peak Load by Source (2000 – 2013)*. Holyoke, MA.

Metropolitan Area Planning Council. 2014. *Metro Boston 2030 Population and Housing Demand Projections*. Boston, MA.

Nadel, S. and R. Young. 2014. *Why is Electricity Use No Longer Growing*, American Council for an Energy Efficient Economy, Washington, DC.

NSTAR (NSTAR Electric Company). 2003 – 2012. *Reports to the City of Cambridge regarding Electricity and Natural Gas Use in the City.* Boston, MA.

_____. 2006 – 2012. *On-Site Generating Facilities Reports*. Filed with MA DPU. Available at MA DOER Distributed Generation and Interconnection in Massachusetts website (https://sites.google.com/site/massdgic/).