City of Somerville

Consumption-Based Emissions Inventory Technical Report

Calendar Year 2019

Prepared by EcoDataLab and AECOM for Mayor Ballantyne's Office of Sustainability and Environment

January 2023

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Glossary

BAU	Business as usual – refers to a future emissions scenario where no further climate action is taken
Category	Consumption-based emissions inventory emissions are categorized into five categories: transportation, housing, food, goods, services
CBEI	Consumption-based emissions inventory – an estimate of the greenhouse gas emissions associated with the activity of all residents of a geographic area
CCE	Community Choice Electricity – Somerville's opt-out program where residents obtain stable electric prices and higher amounts of renewable electricity
Emissions	Refers to greenhouse gas emissions (see *GHG*)
GHG	Greenhouse gas – a gas that absorbs and emits radiant energy within the thermal infrared range, causing the greenhouse effect
$MTCO_2e$	Metric tonne (i.e., 1,000 kilograms) of carbon dioxide equivalent, the common unit for GHG emissions
Per Capita Emissions	GHG emissions per person
Policy	A law, regulation, procedure, administrative action, incentive, or voluntary practice of governments and other institutions
Strategy	A plan of actions, potentially incorporating one or more policies, to achieve an overall goal
"Use phase" emissions	The burning of fossil fuels (such as gasoline or natural gas) for transportation or home heating energy
Sub-category	Each CBEI emissions category consists of multiple sub-categories
VMT	Vehicle miles traveled

Introduction

Somerville aims to become a carbon net negative city by 2050. As a first step in developing a climate change plan to meet this goal, the City established a baseline of greenhouse gas (GHG) emissions and has tracked emissions from City municipal operations as well as emissions in the community, including the residential and commercial sectors, on a biannual basis since 2014. The City has also progressed on goals laid out in the Somerville Climate Forward plan and is updating the plan to include Mayor Ballantyne's carbon net negative goal, both the 2018 and 2020 GHG inventory results, and goals through 2030.

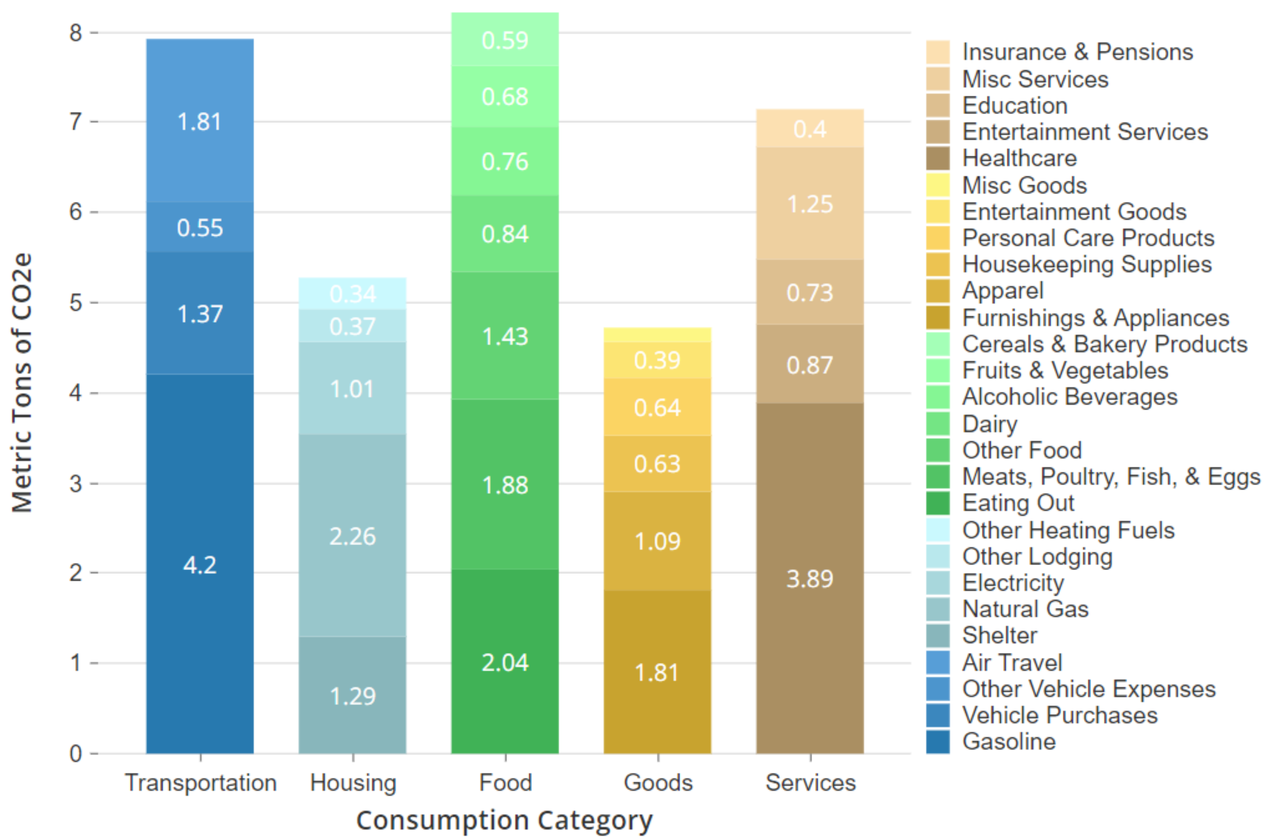
The original Somerville Climate Forward Plan set a goal to complete the community's first consumption-based greenhouse gas inventory. A consumption-based emissions inventory ("CBEI") is an estimate of the GHG emissions associated with the activity of all residents of a geographic area. It is like a personal household carbon footprint estimate, except it is calculated for all households in a jurisdiction. Consumption-based emissions are modeled based on local variables such as income and vehicle ownership, as well as scientific studies that tie these variables to changes in consumption-based emissions.

This CBEI report is completed in line with the Somerville Climate Forward plan and in preparation for forthcoming updates to the plan. This CBEI report includes an assessment of Somerville's consumption-based emissions, including census tract-level variation and historical trends since 2007, as well as forward-looking projections through 2050, a high-level evaluation of potential policies to address those projections, and an assessment of their potential impacts on consumption-based emissions. The appendices to this report include additional information on the methodology used to develop the inventory, additional context around internal discussions that occurred when determining the policies of interest to evaluate, personal actions that Somerville residents can take to reduce their household emissions, the allocation of emissions across lifecycle stages, and consumption-based emissions from government activity.

In 2019, the typical Somerville household was responsible for roughly 33 metric tons of carbon dioxide equivalent ($MTCO_2e$) annually, or about 14 $MTCO_2e$ per person. With 32,120 households in the city, this is a total of roughly 1 million $MTCO_2e$ in 2019 attributable to residents of Somerville. In contrast, the US average is about 41 $MTCO_2e$ per household.

Figure 1 below provides an overview of the city's average per-household emissions in 2019. The actual emissions of any household could vary significantly from this average. Differences in household size, spending, housing, travel, and other discretionary and non-discretionary factors will affect any individual household's emissions.

Figure 1. Somerville Consumption-based Inventory



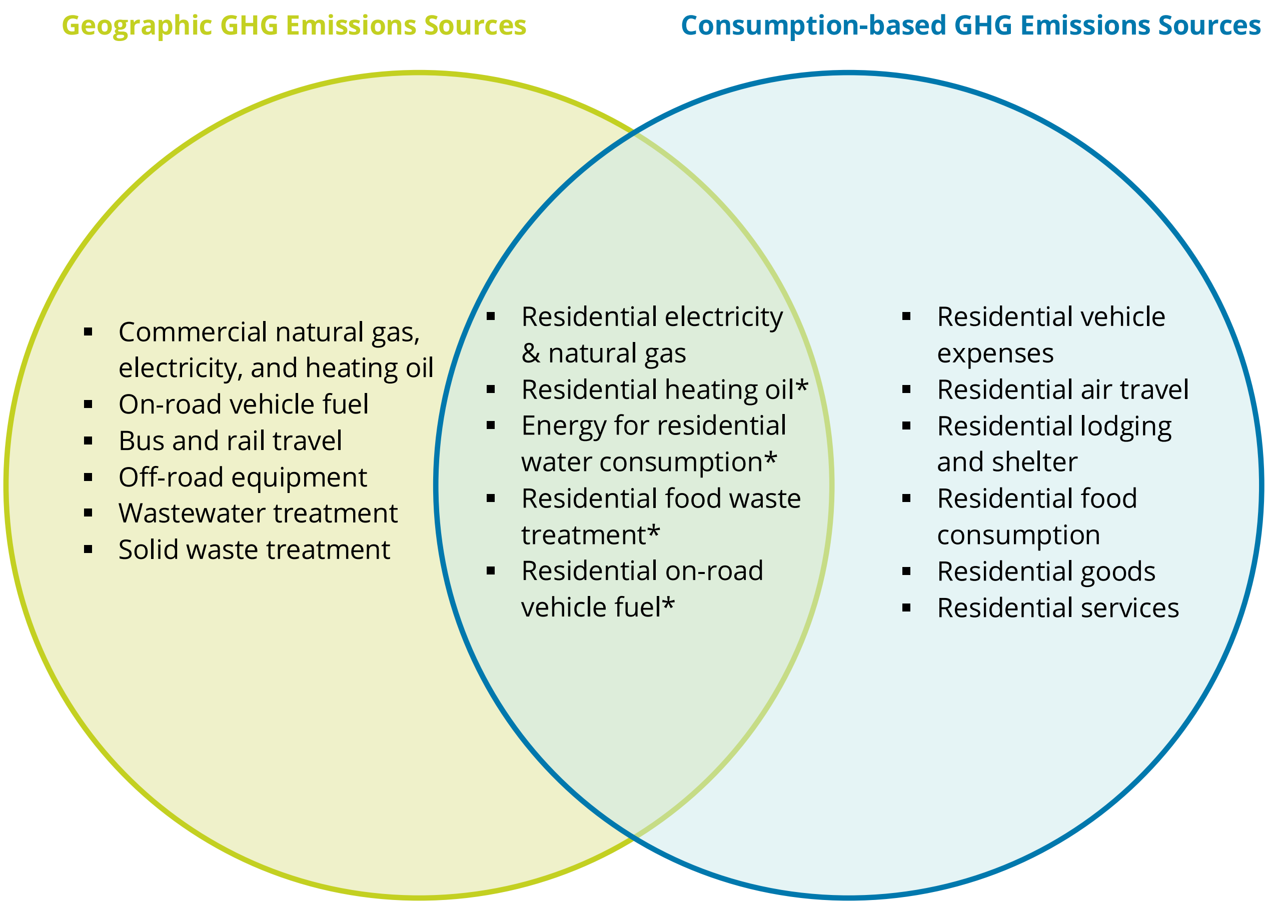
Note: Emissions from the Misc Goods sub-category total 0.16 $MTCO_2e$

Consumption-Based Emissions Approach

CBEIs differ from traditional GHG inventories. In traditional or "geographic" inventories, a city would look at all emissions that occur within the city's borders. In contrast, CBEIs consider emissions that may occur anywhere in the world, if they are directly or indirectly a result of the city's residents' activities.

Geographic and consumption-based approaches are complementary and partially overlapping. Both will look at resident's local, direct emissions (e.g., from driving or home heating). A geographic inventory will also consider the emissions from local businesses and visitors but typically ignore anything outside the city's boundaries. Meanwhile, a consumption-based inventory will omit the local emissions from businesses and visitors, but instead account for emissions associated with resident's travel to other cities, as well as the emissions associated with producing the goods and services they purchase or consume. Those consumption-based emissions may occur anywhere in the world. Figure 2 illustrates the differences and overlap in typical geographic and consumption-based emissions inventories.

Figure 2. Geographic vs. Consumption-Based Emission Sources



**Different methodologies are used to quantify these emissions in each inventory.*

These consumption estimates are developed using a model that primarily considers six key household variables:

- household income,
- vehicle ownership (cars per household),

- household size (people per household),
- home size (rooms per home),
- home ownership, and
- educational attainment (bachelor's degree or higher for at least one member of the household).

These variables often have clear, direct effects on consumption. For instance, larger homes generally take more energy to heat or cool, while more people per household also means more food consumed per household.

The table below compares the values of these variables in Somerville with those of the Massachusetts and US averages as of 2019, using data from the 1-year American Community Survey estimates:

Table 1. Household Characteristics, Somerville vs. MA vs. United States (American Community Survey)

Household Characteristic	Somerville Average (2019)	MA Average (2019)	US Average (2019)
Household Income	$127,108	$112,106	$88,783
Vehicle Ownership (vehicles per household)	1.17	1.64	1.82
Household Size (people per household)	2.44	2.51	2.61
Home Size (rooms per home)	5.45	6.35	6.57
Rate of Home Ownership	35%	62%	64%
Educational Attainment (bachelor's degree or higher per household)	65%	48%	36%

The emissions profile for Somerville is based on an average household in 2019, using the overall average household characteristics for Somerville. Most actual households in the city differ in one or more ways. For Somerville, the average household has 2.44 people, living in a 5.45-room home, with 1.17 vehicles and an annual income of $127,108. Households with different characteristics are expected to have different emissions profiles.

Individual households may estimate their carbon footprint by using personal household carbon footprint calculators, such as the one provided by the University of California at Berkeley CoolClimate Network: https://coolclimate.org/calculator

For a more detailed breakdown of how these and other factors affect emissions, see Appendix B.

Major Categories of Consumption-based Emissions and Detailed Breakdown

With reference to Figure 1, among all categories, Food, Transportation, and Services are the largest overall emissions categories in Somerville, accounting for 25%, 24%, and 21% of emissions, respectively. Together, these account for approximately 70% of total emissions. Each of these categories also includes multiple sub-categories. Across all sub-categories, gasoline, healthcare, and natural gas are the top three emissions sources, accounting for 13%, 12%, and 7% of total emissions, respectively, a combined 31%.

The following sections discuss each category in greater detail, along with further discussions of certain sub-categories of particular interest.

Food

The food category includes all food consumed by residents of Somerville, broken down by meat, dairy, fruits and vegetables, other foods consumed at home, as well as dining out. Food accounts for 8.2 $MTCO_2e$ (25% of total consumption-based emissions), and the single largest sub-category is dining out at 2 $MTCO_2e$, or 25% of total food emissions.

Globally, roughly 24% of GHG emissions are a result of agriculture, forestry, and other land use changes, with most of these emissions resulting from agriculture. In the US, agriculture resulted in roughly 623 million $MTCO_2e$ in 2019, or about 10% of national emissions, according to the US Environmental Protection Agency's (EPA) most recent national inventory.[1]

Emissions from agriculture are driven primarily by two sources. In the US, most agricultural emissions derive from nitrous oxide (N_2O), a greenhouse gas that is

[1] US EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019" https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2019

released from the breakdown of nitrogen-based fertilizers. Nitrous oxide accounts for roughly 55% of US agricultural greenhouse gas emissions.

The second-largest source of agricultural emissions is methane (CH_4), a potent greenhouse gas which is produced by certain animals like cows, sheep, and goats. These animals rely on microbes to break down the grass and other plants they eat, in a process known as enteric (or intestinal) fermentation. This digestive fermentation produces methane as a byproduct, much in the same way that beer fermentation produces CO_2 as a byproduct. Methane from digestion accounts for nearly 30% of the US GHG emissions from agriculture. The decomposition of animal manure (also into methane) contributes another 12% of agriculture emissions. Nitrous oxide and methane combined account for 97% of emissions directly associated with agriculture.[2]

The consumption-based emissions inventory includes these direct nitrous oxide and methane emissions from agriculture, emissions from fixed capital investments in agricultural equipment and facilities, as well as emissions associated with the transport and sale of food. In the consumption-based emissions inventory, direct emissions from agriculture represent most of the emissions associated with food. Generally, around 67-80% of food emissions come directly from food production (see Appendix D: Emissions Breakdown by Supply Chain Stage). For most foods, transportation comprises about 5% of the emissions, while wholesale and retail make up another 5-15%. Typically, fixed capital investments (e.g., buildings and equipment) is estimated around 13% of total emissions.

While nitrous oxide from nitrogen fertilizer is the single largest source of agricultural emissions nationally, meat and dairy are often the largest sources of at-home food emissions for households. In Somerville, meat, poultry, fish, eggs, and dairy combined account for 2.7 $MTCO_2e$ of emissions, while fruits and vegetables, cereals, and other foods account for an additional 2.7 $MTCO_2e$.

Despite being only a small fraction of overall calories consumed, meat and dairy have an outsized impact on the typical household's emissions associated with food. This is because the emissions associated with meat consumption includes the direct methane emissions from the animals, as well as the nitrous oxide emissions from growing all the crops to feed those animals.

[2] ibid

It takes a lot of feed crop, mostly corn,[3] to produce one calorie of meat. In the case of beef, it can be as many as 33 calories of feed per calorie of beef.[4] As a result, a quarter pound of beef (284 calories) could require over 9,000 calories of corn to produce.

Further compounding these food emissions is the fact that an estimated 30-40% of food goes to waste.[5] Emissions from the production of wasted food is included in the overall emissions associated with food, which increases the emissions of all food consumption. While some of this loss occurs in production, storage, or transport, households are often also a significant source of food waste. According to the United Nations, US households purchase more calories per capita than any other country, nearly 3,800 calories per person per day in 2018.[6] This includes all purchased food, whether consumed or otherwise.

Dining out, such as at restaurants, also contributes to a portion of food emissions. For the typical Somerville household, dining out is associated with roughly 2 $MTCO_2e$ per year. However, this includes all the food consumed while dining out, as well as the operational emissions from restaurants, including emissions from cooking, transportation, and construction of the building. In comparison, household emissions from cooking, transportation, and construction are allocated to the transportation and housing sectors. Overall, dining out likely has similar emissions per calorie as food prepared at home; though restaurants across the US often also serve much larger portions than are typically consumed at home, which can lead to further food waste or excess.

Transportation

The transportation category includes gasoline usage, vehicle purchases and maintenance, and air travel. For an average household in Somerville, transportation accounts for 7.9 $MTCO_2e$ per year, per household (approximately 24% of total consumption-based emissions). Much of this comes from gasoline, which accounts for 4.2 $MTCO_2e$, or 53% of the total transportation emissions.

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[3] US Department of Agriculture, "Feedgrains Sector at a Glance" https://www.ers.usda.gov/topics/crops/corn-and-other-feedgrains/feedgrains-sector-at-a-glance/

[4] A Shepon et al 2016 *Environ. Res. Lett.* 11 105002 https://iopscience.iop.org/article/10.1088/1748-9326/11/10/105002/pdf

[5] US Department of Agriculture, "Food Waste FAQs" https://www.usda.gov/foodwaste/faqs

[6] United Nations Our World in Data, "Food Supply" https://ourworldindata.org/food-supply

Gasoline

Gasoline consumption is the top source of consumption-based emissions in Somerville, responsible for 4.2 $MTCO_2e$ per household. There are two key components that drive gasoline consumption: vehicle ownership and the amount of driving per vehicle.

The average US household has about 1.8 vehicles.[7] A typical vehicle is driven over 11,000 miles per year,[8] and so the average American household drives approximately 20,500 miles per year.

Meanwhile, Somerville households have an average of 1.17 vehicles per household and drive an estimated 8,480 miles per year. This results in approximately 7,248 miles per vehicle, or 64% of the average American.

Twenty three percent (23%) of households in Somerville are car-free. Somerville also has a population density of over 19,000 people per square mile, making it relatively easier to fulfill most daily errands without a car in much of the city.

Air Travel

For many individual households, air travel is a significant portion of emissions. However, for Somerville overall, air travel is only a small part of the city's consumption-based emissions, contributing approximately 1.8 $MTCO_2e$ per household on average (5.4% of total emissions). This varies significantly between households largely due to income. Air travel is a luxury for most households, and only the wealthiest households do substantial flying.

According to Gallup survey data, between 1999 and 2015, 48-60% of the US population did not fly in any given year.[9] More recent data from Statista.com suggests that in 2019, 41% of the US population 18 and older had never traveled by air, and another 28% flew only about once per year.[10]

Air travel in a mostly full aircraft is more fuel efficient than driving alone, but the high-altitude pollution released is uniquely damaging to the environment and can

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[7] 2019 American Community Survey (ACS) 5-Year Estimates: https://data.census.gov/table
[8] Alternative Fuels Data Center (AFDC), https://afdc.energy.gov/data/10309
[9] Gallup, Airlines: https://news.gallup.com/poll/1579/airlines.aspx
[10] Statista, Air travel frequency in the United States in 2019: https://www.statista.com/statistics/539473/airline-travelers-number-of-trips/

make flying worse than driving. Most modern aircraft get roughly 70-100 miles per gallon per passenger seat,[11] with fuel economy improving for longer flights. In comparison, the average fuel economy for new vehicles nationwide was 25.4 miles per gallon in 2020.[12] Due to additional climate effects from high-altitude particulate matter, as well as lifecycle production of aviation fuels, air travel's overall emissions are roughly double what would be expected on a per gallon basis alone, making it more like driving a 35-50 miles per gallon car. As a result, air travel may be more fuel-efficient than driving alone in an average vehicle, but usually not if two or more individuals are traveling together, or for a single individual in a very efficient or all-electric vehicle. Very short flights (less than 300 miles) typically have extremely poor fuel economy and may not be more fuel efficient than driving alone in an average vehicle.

Air travel also often results in significant emissions due to the long distances traveled. A two-person, one-vehicle household may only drive 10,000 miles per year but could easily fly 24,000 person-miles with just two cross-country trips per year (3,000 miles one way).

Services

The services category includes all services used by residents, such as healthcare, entertainment, education, personal care services, financial services, and more.

Services account for 7.1 $MTCO_2e$ per household (approximately 21% of total consumption-based emissions), and the single largest sub-category is healthcare at 3.9 $MTCO_2e$, or 54% of total Service category emissions. Healthcare produces most emissions from services primarily because it is a large economic sector. Nationally, healthcare makes up roughly 18% of the US economy. In Somerville, healthcare emissions are about 12% of the average household's carbon footprint. Healthcare emissions include emissions from the construction and operation of hospitals, doctor’s offices, and other medical facilities, manufacturing of pharmaceuticals and medical equipment, and more.

Other major categories of emissions include entertainment services (mostly fees and admissions to museums, concerts, etc.), education, financial services like

[11] Wikipedia, Fuel Economy in Aircraft: https://en.wikipedia.org/wiki/Fuel_economy_in_aircraft#Regional_flights
[12] Environmental Protection Agency, Highlights of the Automotive Trends Report: https://www.epa.gov/automotive-trends/highlights-automotive-trends-report

insurance and pensions, and miscellaneous services (including personal care, household operations, etc.). These are generally smaller categories because average households spend much less on these other services. However, households with an adult who has a college degree tend to spend more on entertainment services, financial services, personal care products and services, and education. Somerville is a very highly educated community, but because of its other household characteristics, such as smaller household size, it still has lower emissions per household from services than the US average.

Housing

Household energy use, home construction and maintenance (shelter), water, and waste make up the housing category. Overall, a typical Somerville household is responsible for 5.4 $MTCO_2e$ resulting from housing (approximately 16% of total consumption-based emissions). Natural gas is the largest single sub-category and produces nearly 2.3 $MTCO_2e$, or approximately 42% of the total housing category emissions.

Natural Gas

Natural gas is a common fuel for home heating, water heating, clothes drying, and cooking. The primary ingredient of natural gas is methane, a potent greenhouse gas. Most GHG emissions associated with natural gas result from burning the gas to produce heat, which also emits carbon dioxide. In addition, some methane is leaked into the atmosphere during the extraction, processing, and transport (piping) of natural gas into homes.

Burning natural gas in homes contributes to carbon dioxide emissions and to local indoor and outdoor air pollution. Natural gas combustion produces carbon monoxide, nitrogen dioxide, fine particulate matter (PM2.5), and formaldehyde, among other pollutants.[13] When burned in furnaces for heating or water heating, these fumes are vented into the surrounding neighborhood, where they generally disperse at low concentrations. When burned in a gas stove or oven, these fumes are emitted directly into residential living spaces, which are often not adequately vented. As a result, gas stoves can lead to dangerously elevated levels of indoor air

[13] California Air Resources Board, "Combustion Pollutants & Indoor Air Quality" https://ww2.arb.ca.gov/resources/documents/combustion-pollutants-indoor-air-quality

pollution.[14] Even moderately well-ventilated homes with gas stoves can have elevated levels of air pollutants that increase the risk of asthma in children and exacerbate asthmatic symptoms in adults.[15]

Methane extraction, transport, storage, and distribution systems nationwide typically have small leaks. Methane itself is a much more potent greenhouse gas than carbon dioxide. One ton of methane has the same warming impact as nearly 30 tons of carbon dioxide when considered over a 100-year time frame, and 80-90 tons of carbon dioxide when considered over a 20-year time frame. As a result, if even just 5% of a given quantity of methane is lost to leaks, it would mean that the leaked methane is a bigger contributor to climate change than the carbon dioxide from burning the other 95%. In 2019, the national average leakage rate throughout the entire natural gas supply chain was about 2.3%.[16]

Nationally, the EPA estimates about half of all methane leaks occur in production, with another 25% occurring in transmission and storage.[17] Distribution and post-meter leakage each contribute about 10% to the overall leakage rate. The consumption-based inventory uses the 2.3% overall leakage rate.

Natural gas usage for Somerville is roughly 428 therms per household, resulting in nearly 2.3 $MTCO_2e$. About 75% of households in the city use gas for space heating.

Electricity

Somerville's electricity emissions were calculated from Eversource and Somerville Community Choice Energy (Somerville CCE) data showing an average electricity usage of 4,678 kilowatt hours (kWh) per household and a weighted average emissions factor of 215 grams per kWh, resulting in about 1 metric ton per year. This is substantially below the average Massachusetts household, which uses over 6,000 kWh per year. Somerville's electricity is about as clean as the regional average, with the New England region overall having an emissions factor of 222

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[14] Rocky Mountain Institute, "Gas Stoves: Health and Air Quality Impacts and Solutions" https://rmi.org/insight/gas-stoves-pollution-health/

[15] American Journal of Respiratory and Critical Care Medicine, "Indoor air pollution and asthma. Results from a panel study." https://www.atsjournals.org/doi/abs/10.1164/ajrccm.149.6.8004290

[16] The Conversation, "The US natural gas industry is leaking way more methane than previously thought. Here's why that matters" https://theconversation.com/the-us-natural-gas-industry-is-leaking-way-more-methane-than-previously-thought-heres-why-that-matters-98918

[17] US EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019" https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2019

grams per kWh. Roughly 14% of households in Somerville use electricity for heating.

Water

The average household in Somerville uses an estimated 51,390 gallons of water per year. With an estimated emissions factor of 3.2 grams of CO_2e per gallon, the average household has roughly 0.16 $MTCO_2e$ associated with its water use. As a result, water consumption is not a significant contributor to consumption-based emissions, though improved water conservation does provide other important environmental benefits.

Goods

The Goods category includes all physical items purchased by households (excluding items in other categories, like food and fuel). Goods includes things like furniture, personal electronics, clothing, personal care products, toys, and books. These goods account for 4.7 $MTCO_2e$ per household per year (approximately 14% of total consumption-based emissions). Of these goods, furnishings and appliances is the single largest source, making up 1.8 $MTCO_2e$, or 38% of total goods emissions.

Generally, goods have lower emissions per dollar than food or energy. Households with higher incomes tend to spend more money, as well as a greater fraction of their income, on these various goods and services. Homeowners tend to spend more on home furnishings and equipment.

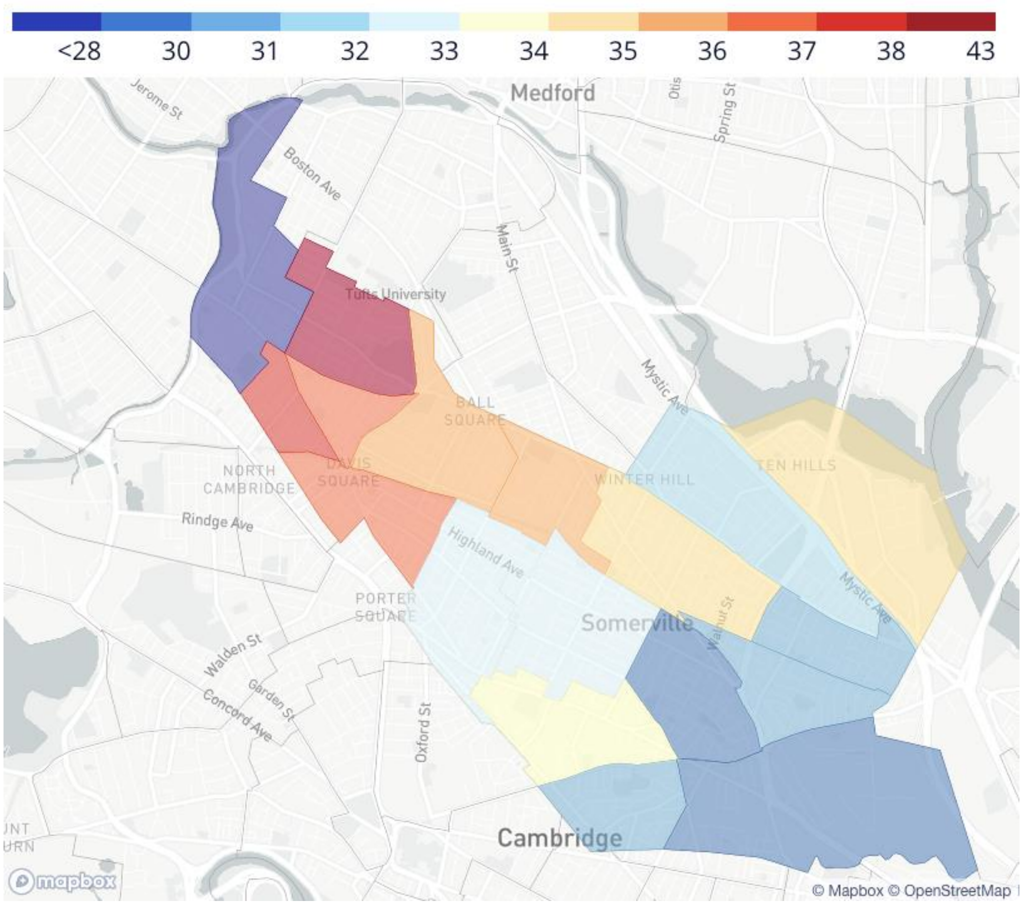
In Somerville, the largest sources of emissions in this category come from household furnishings and equipment, including miscellaneous household equipment, furniture, and appliances, as well as apparel (clothing).

Neighborhood Variation

Among the 18 census tracts in Somerville, there is substantial variation in both emissions and the key household characteristics that drive emissions. This section includes a series of maps illustrating the variations across the city.

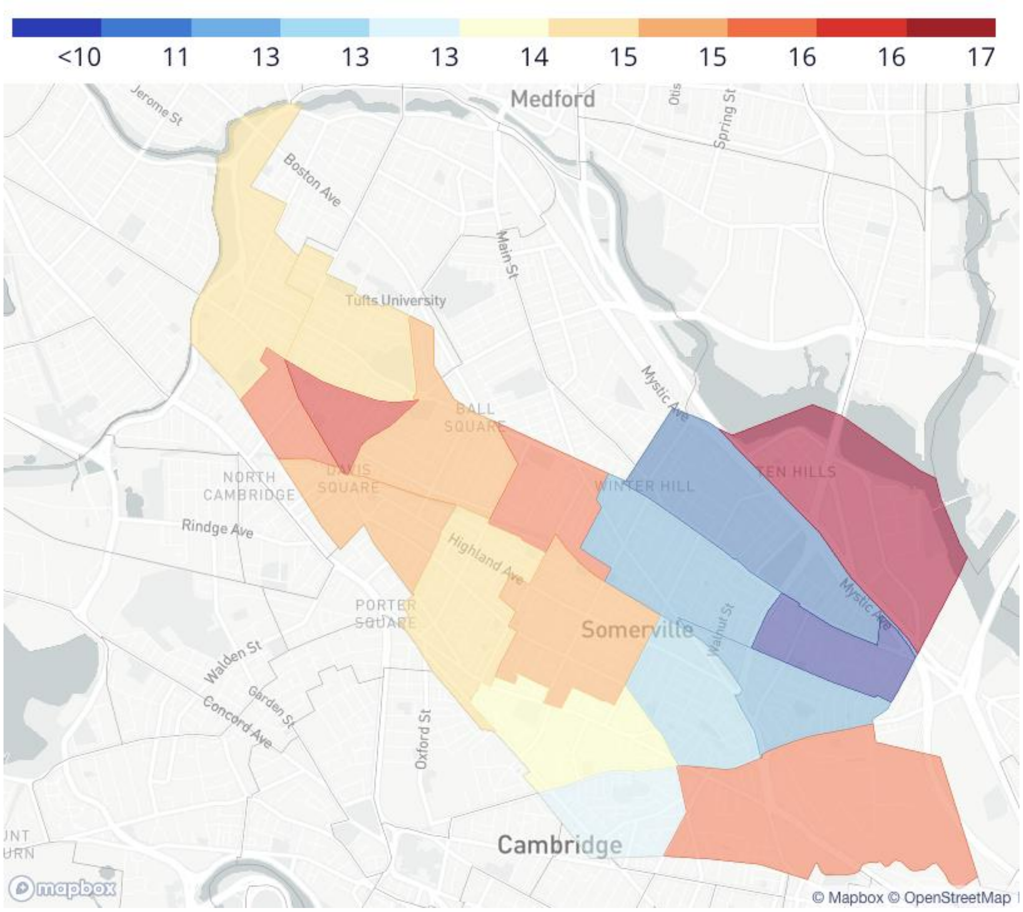
The city's highest-emitting neighborhood has per-household emissions of 43 $MTCO_2e$, while households in the lowest-emitting neighborhood have emissions of 28 $MTCO_2e$, roughly 35% less (see Figure 3).

Figure 3. Consumption-based Emissions Map ($MTCO_2e$ per household)



These differences remain on a per-capita basis but shift their relative neighborhoods. Somerville's highest per-capita neighborhoods have emissions of 17 $MTCO_2e$, while households in the lowest-emitting neighborhood have emissions of 10 $MTCO_2e$, roughly 41% less (see Figure 4).

Figure 4. Consumption-based Emissions Map ($MTCO_2e$ per person)



The variation in emissions between neighborhoods (shown in Figures 3 and 4) is driven by a wide range of factors. The following series of maps show how six core household characteristics vary across the city, with subsequent implications for consumption-based emissions, including:

1) income,
2) household size,
3) vehicle ownership,
4) home size (number of rooms),
5) home ownership, and
6) education.

Figure 5. Somerville Average Household Income Map

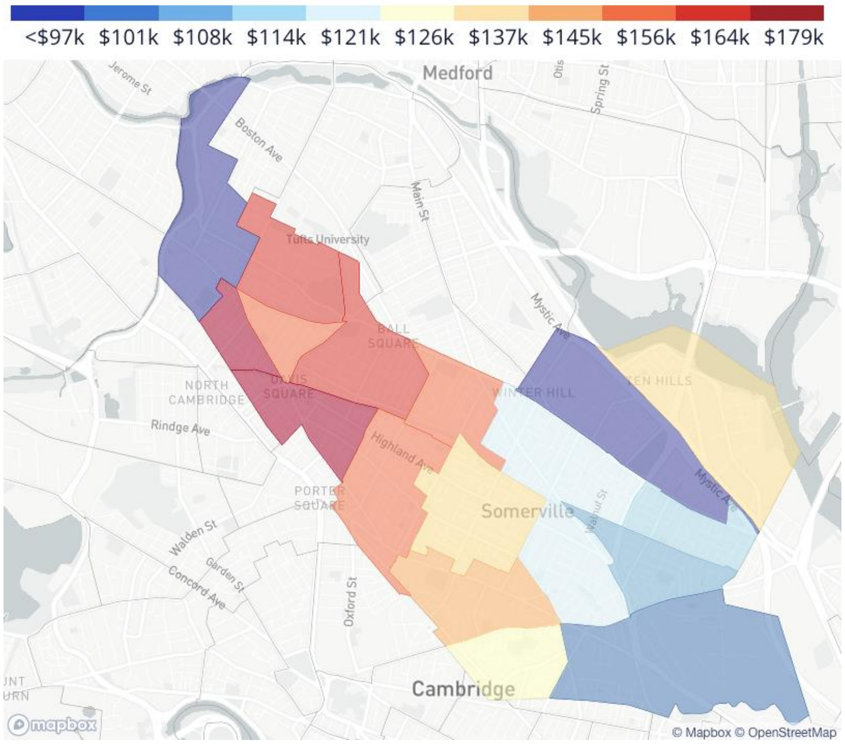


Figure 6. Somerville Household Size Map

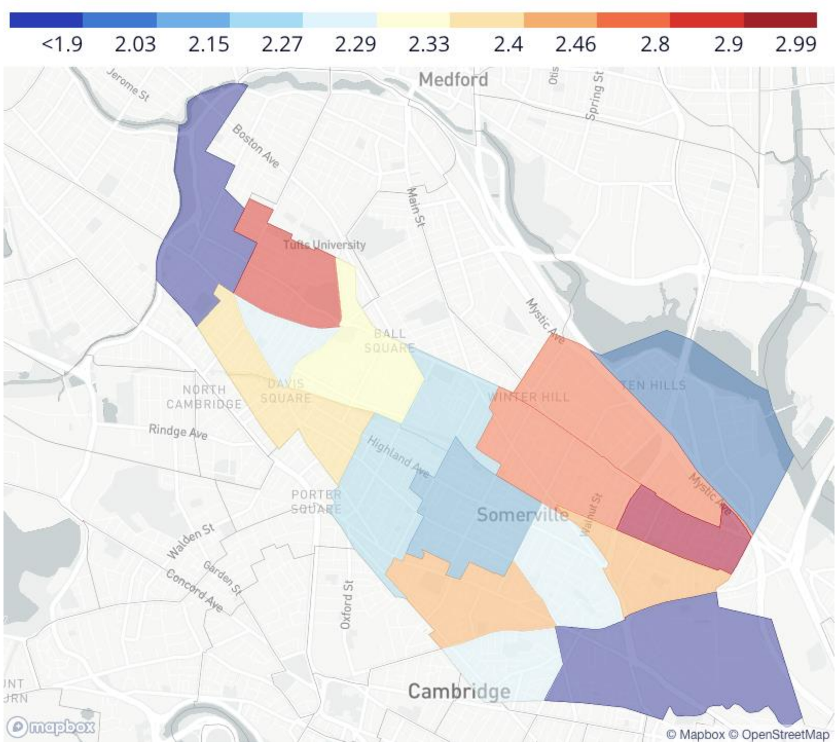


Figure 7. Somerville Vehicle Ownership Map

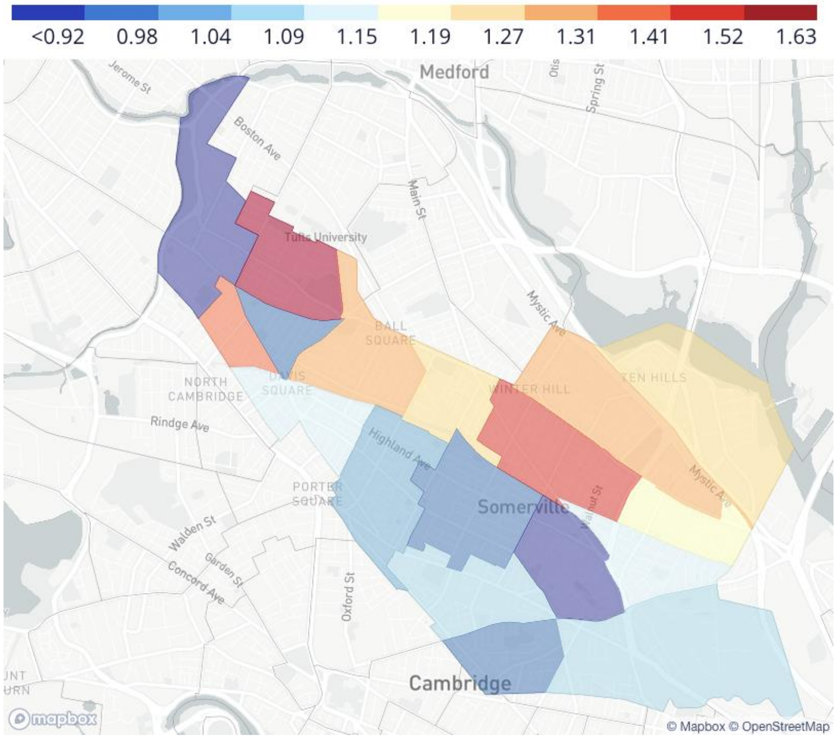


Figure 8. Somerville Rooms per Household Map

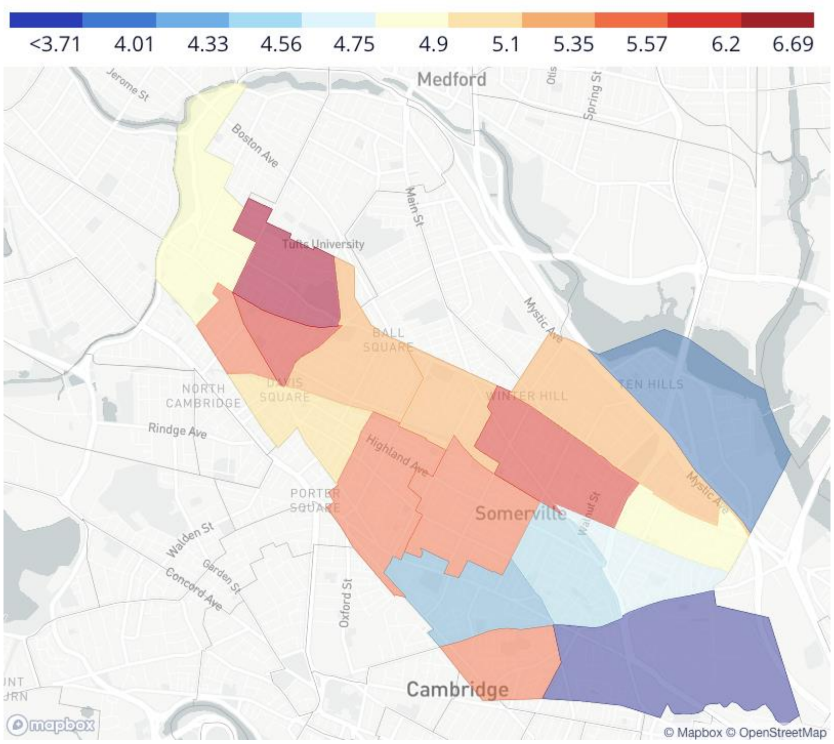


Figure 9. Somerville Home Ownership Map

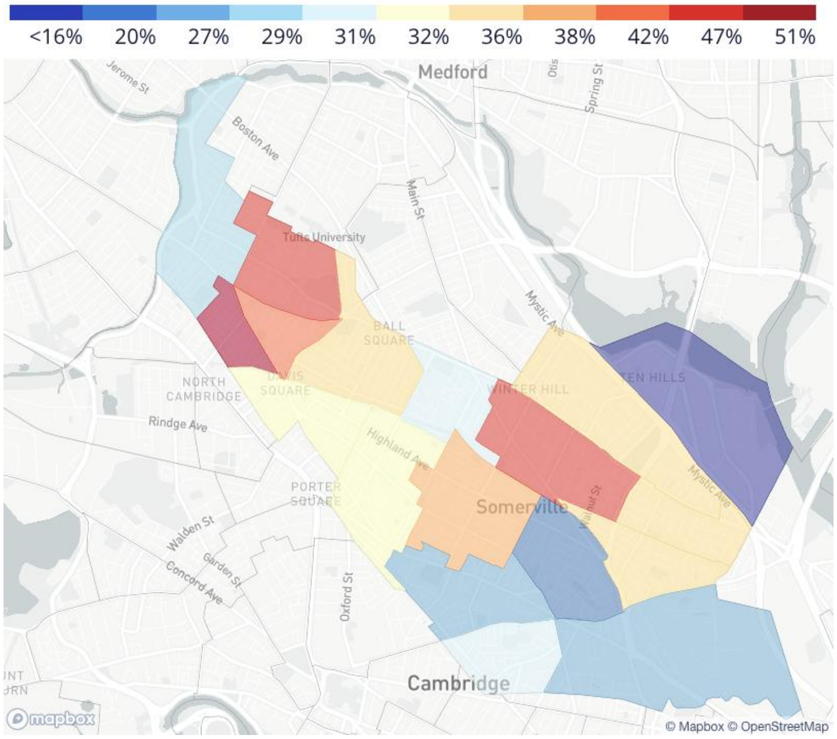
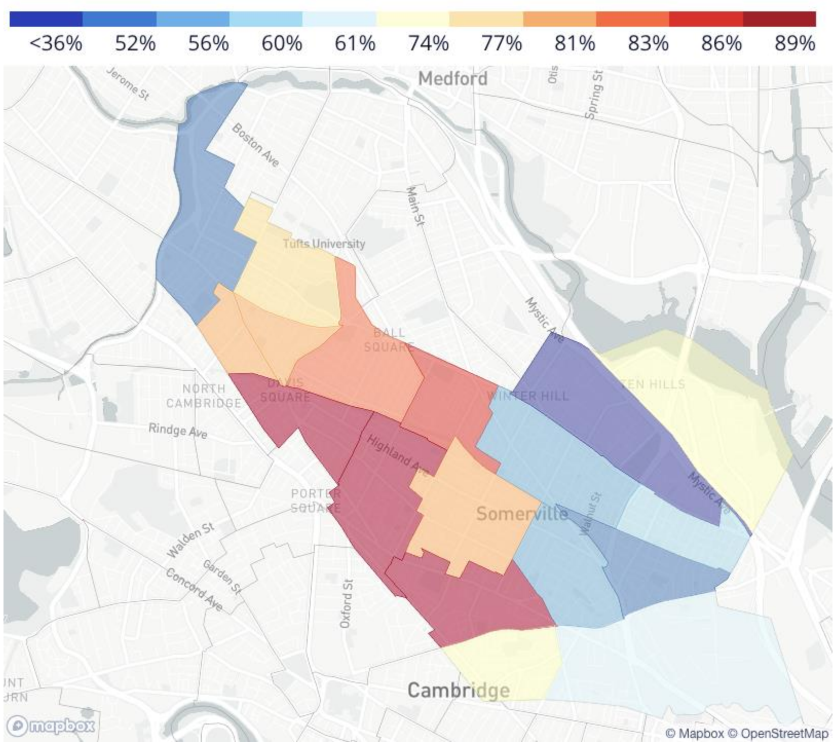


Figure 10. Somerville College Degree Attainment Map



Somerville has exceptionally low average per-household emissions. The city benefits from a compact urban form that makes it among the most walkable and transit-friendly cities in the nation. The city's historical land use plans and development patterns have encouraged smaller, multifamily homes across large areas of the city. Because more people and destinations are closer together, Somerville is more walkable and has more public transit options available. As a result, households in Somerville have much lower vehicle ownership than average and are much less likely to drive to work.

Two-thirds of housing units are rented in Somerville, leading to lower rates of home ownership. Smaller housing units also means the number of people living in one housing unit (households) tends to be smaller. Multi-unit dwellings also require substantially less energy to heat and cool each home, reducing emissions in the housing category.

Somerville also faces certain challenges from sharply rising incomes and increasing educational attainment among its residents. These patterns are common in cities that are facing gentrification challenges due to insufficient housing construction. Somerville will need to address these housing issues to effectively manage future consumption-based emissions and enhance equity.

Figures on the following pages provide some examples of how these neighborhood characteristics correlate with per household emissions across the city.

Figure 11 shows census tracts in the city by average household income (horizontal axis) versus household carbon footprint (vertical axis). Each dot represents a census tract (neighborhood). Higher incomes strongly correspond to greater consumption emissions. Somerville's relatively uniform and compact development patterns mean that there is little variation in household emissions between neighborhoods at similar income levels: while higher-income households tend to have higher emissions, Somerville's built environment does not facilitate high-emission lifestyles, even for its wealthiest residents.

Figure 11. Household Income vs. Emissions

Figure 12 shows census tracts in the city by number of vehicles owned (horizontal axis) versus household carbon footprint (vertical axis). Each dot represents a census tract (neighborhood). Greater vehicle ownership strongly corresponds to greater emissions, almost entirely due to the increased driving associated with the extra vehicle(s). Households with more vehicles may be wealthier, and thus able to afford the extra vehicle, or they may also be lower income and have a job that is inaccessible by transit or unable to afford to live close to transit. Some factors that serve to decrease transit usage may include but are not limited to the location of a home or job, accessibility constraints, or public transit operating hours.

Figure 12. Vehicle Ownership vs. Emissions

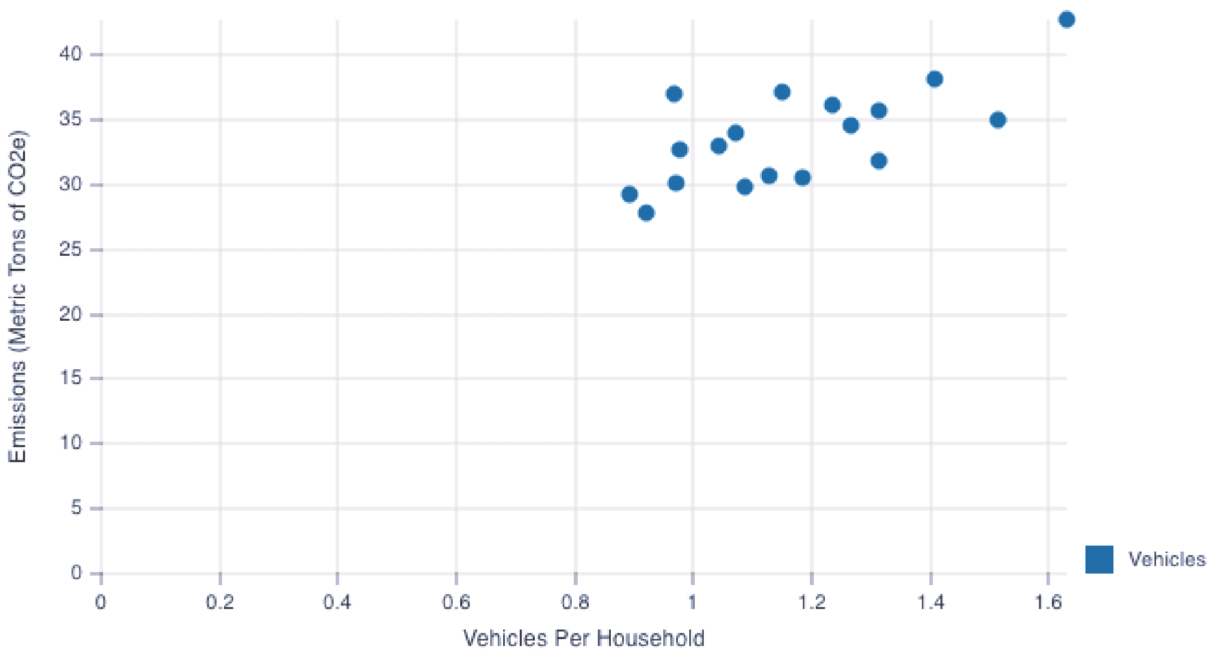


Figure 13 shows census tracts in the city by number of rooms per home (horizontal axis) versus household carbon footprint (vertical axis). Each dot represents a census tract (neighborhood). More rooms per home strongly corresponds to greater emissions – homes with more rooms take more energy and associated emissions to heat or cool and have more space to accommodate more purchases of furniture and other household goods.

Figure 13. Rooms vs. Emissions

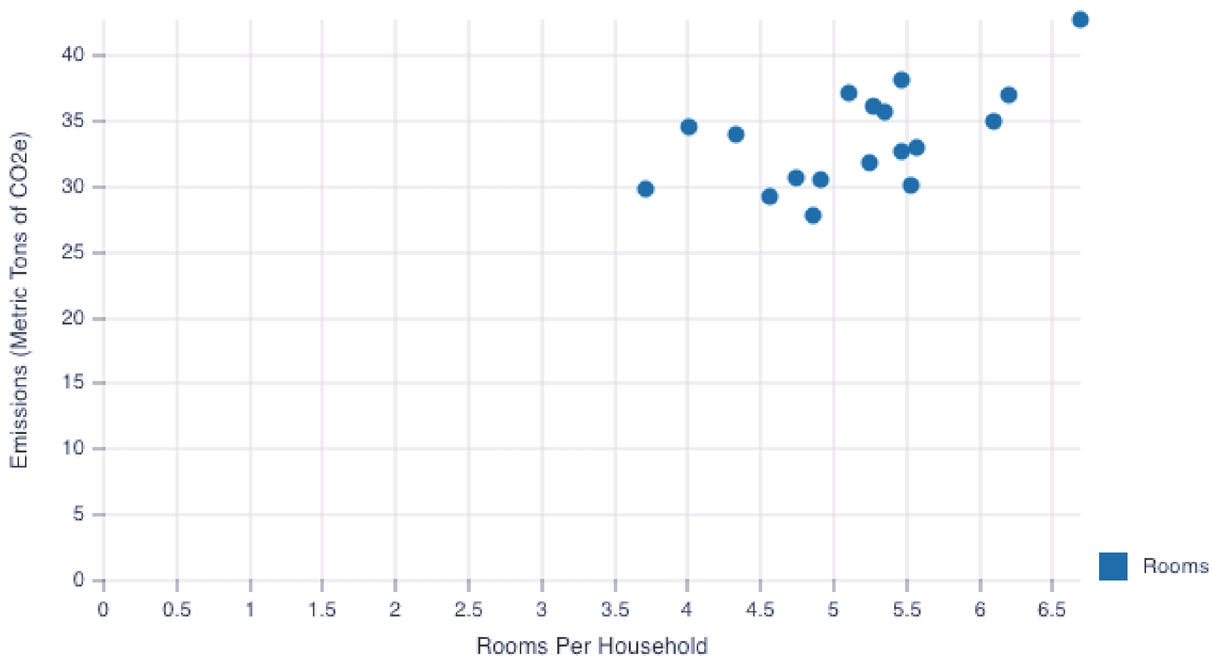
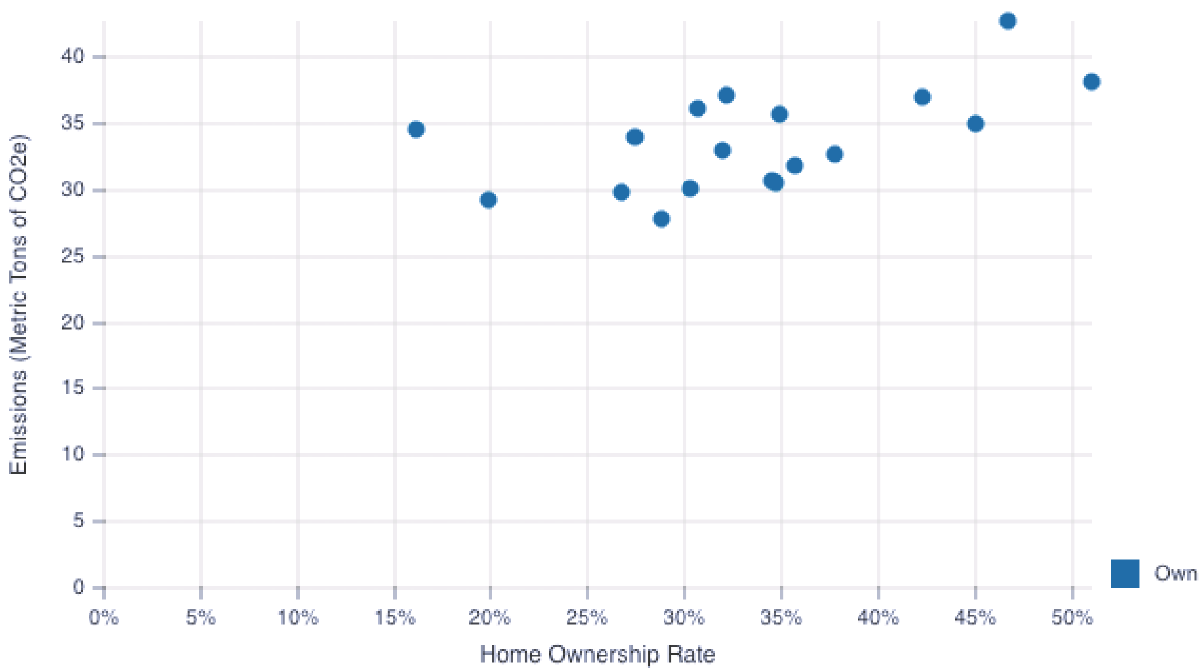


Figure 14 shows census tracts in the city by percent of households which own their home (horizontal axis) versus household carbon footprint (vertical axis). Each dot represents a census tract (neighborhood). Greater home ownership strongly corresponds to greater emissions. This is partly because home ownership correlates with income and household size. It is also because home ownership on its own leads to more consumption of goods that are higher emissions. For instance, this may include consumption of furniture and miscellaneous housewares.

Figure 14. Home Ownership vs. Emissions



Historical Trends

Data for the consumption-based emissions inventory spans back to 2007. For this analysis, the full range of historical trends was used.

Since 2007, emissions per household have changed by -0.2%, or -0.1 $MTCO_2e$ per household, as show in Figure 15 and Table 2.

Figure 15. Historical CBEI trends

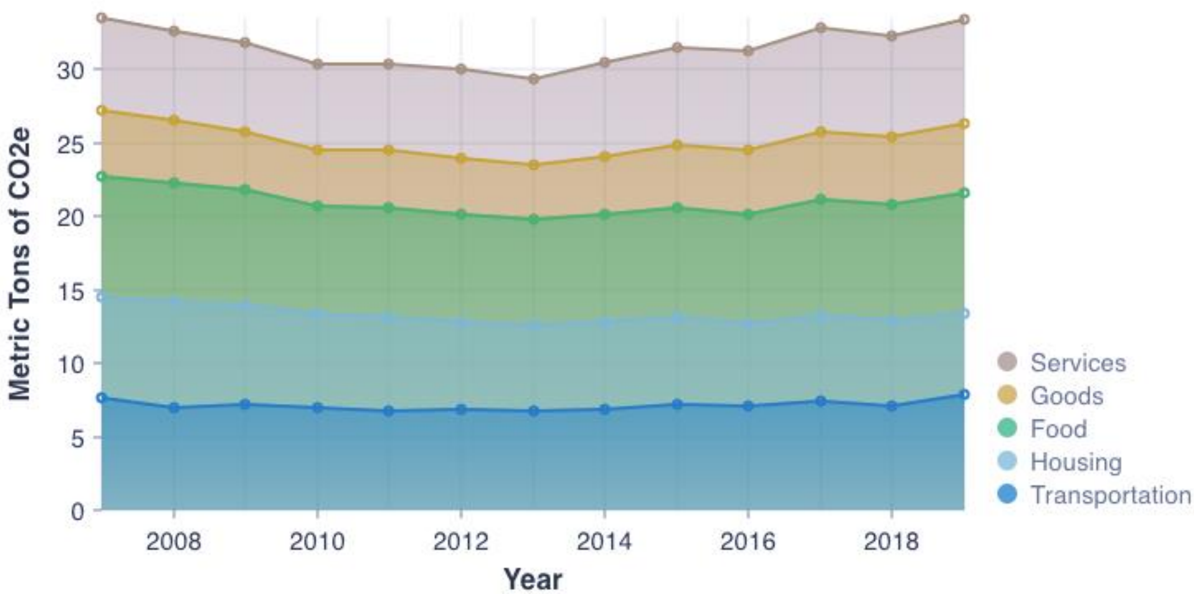


Table 2 compares emissions in 2007 and in 2019 on a per household basis (unless otherwise stated). The services and goods categories have seen the largest emissions increases, of 14% and 5%, respectively.

Table 2. Somerville Changes in Emissions Over Time (2007-2019)

Emissions Category	Somerville (2007)	Somerville (2019)	% Change
Total Per Household Emissions	34	33	-0.2%
Food Emissions	8.3	8.2	-0.8%
Transportation Emissions	7.7	7.9	2.9%
Services Emissions	6.2	7.1	12.6%
Housing Emissions	6.8	5.4	-24.8%
Goods Emissions	4.5	4.7	4.8%
Total Per Capita Emissions	14.3	13.7	-4%

At a national level, the carbon intensity of goods and services has been declining. The electricity grid has been getting cleaner (with increases in renewable energy sources, for example), vehicle fuel economy has been improving, and industries have generally been successful in producing more with less emissions. Somerville has also seen significant demographic changes over this same period. Since 2007, average household incomes have increased by over $52,000, or 69%. Even after adjusting for inflation, this is an increase of 37% (see Figure 16). The share of households with a college degree has also grown substantially, from 50% to 65% (see Figure 17). Vehicle ownership, home size, and home ownership rates have remained largely flat (see Figure 18).

Figure 16. Income Over Time

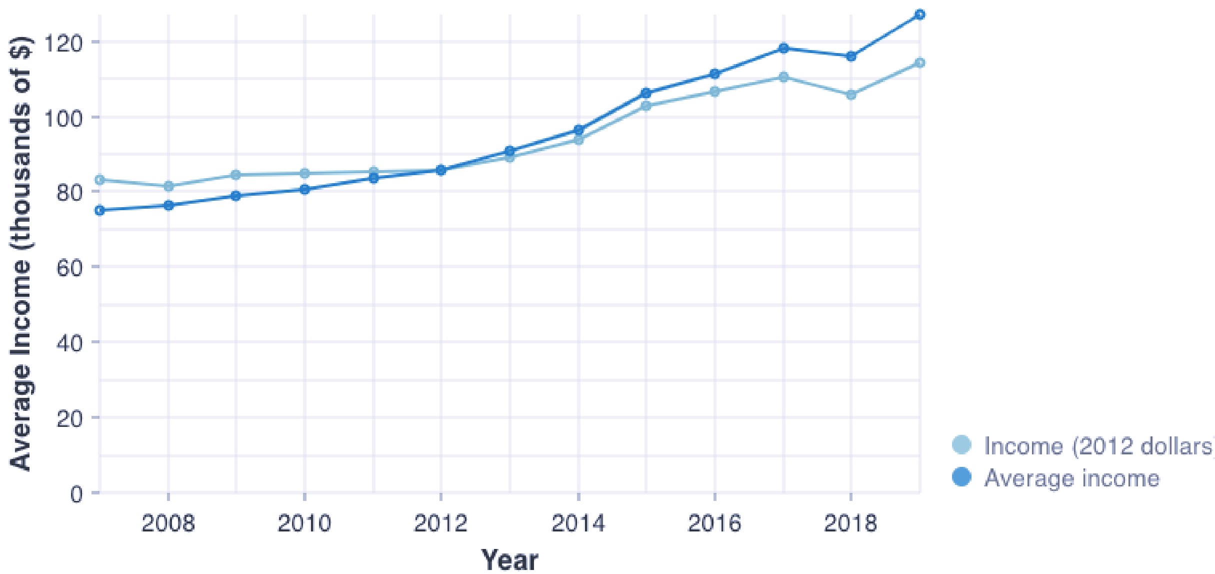


Figure 17. Percent with College Degree and Homeownership Rate Trends

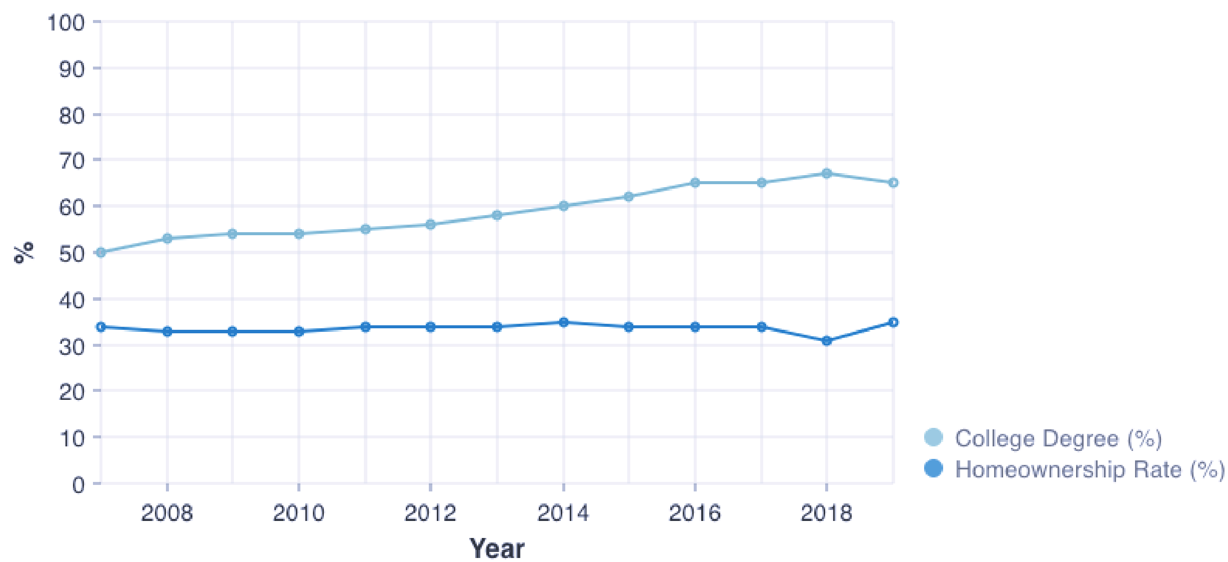
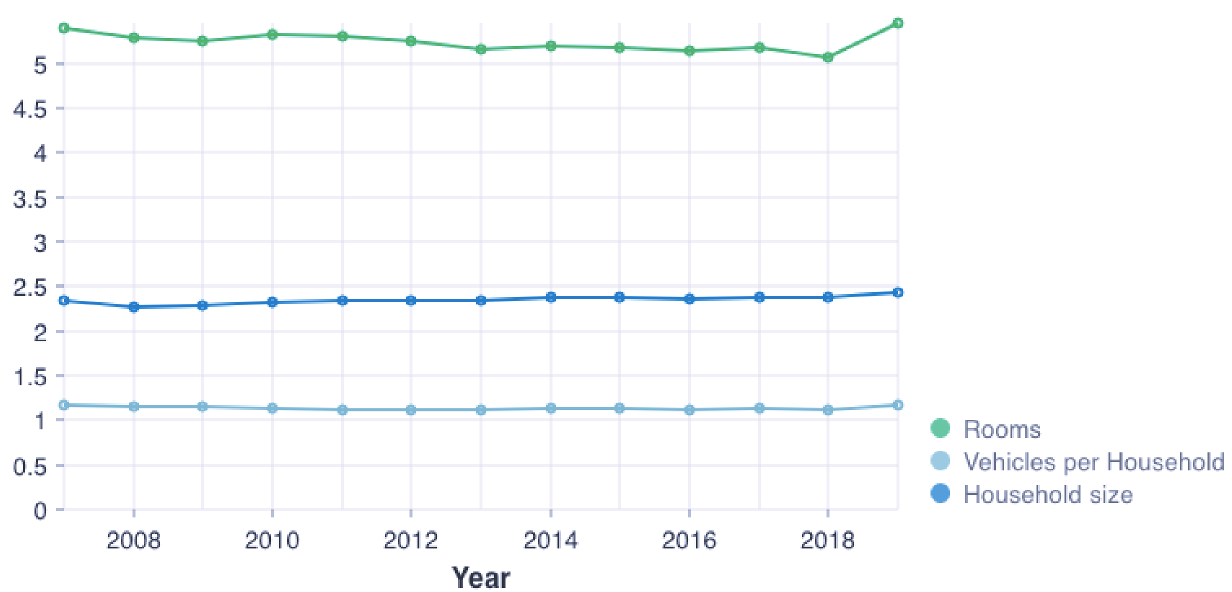


Figure 18. Rooms, Vehicles per Household, and Household Size Trends Over Time



Business-as-Usual Analysis & Findings

Business-as-usual (BAU) is a common GHG emissions forecasting (or future projection) term that means continuing existing policies and behaviors under their current trends and projections, without additional intervention.

This BAU analysis assumed that most household characteristics remained at their 5-year average after 2019, including home ownership, home size, household size, average income, and educational attainment, based on review of data and discussion with city staff. Two key drivers of change in the BAU included:

1) Massachusetts' adoption of California's Advanced Clean Cars II ruling (ACCII), which requires 35% of vehicles sold to be zero-emission by 2026 and 100% by 2035. This regulation is expected to result in 100% zero-emission vehicles on the road by 2050.
2) Massachusetts' Renewable Energy Portfolio Standard (RPS), moving from 18% renewables in 2019 to 100% by 2050. Presently, about 75% of Somerville electricity customers are enrolled in Somerville CCE, almost all of which are signed up to receive 20% more renewable power than the grid average. For simplicity in the BAU, this was assumed to be a citywide average of 10% more renewable energy than the Massachusetts grid average. Because Massachusetts is projecting to reach approximately 90% clean electricity by 2030,[18] this simplified assumption means that Somerville is projected to reach 100% clean electricity by 2030 under the BAU model.

In addition, the BAU also assumed that average household vehicle ownership declined to 1.0 vehicles per household by 2030, down from 1.17 in 2019, primarily due to the opening of the Green Line Extension and anticipated development of Somerville's Bicycle Network Plan.[19] The BAU also assumes a slight increase in

[18] Massachusetts Department of Environmental Protection, "310 CMR 7.75 Clean Energy Standard (CES) Frequently Asked Questions (FAQ) Version 2.2 (December 2022)" https://www.mass.gov/doc/frequently-asked-questions-massdep-clean-energy-standard/download
[19] 1.0 vehicles per household is based on projected ridership, current commute patterns, and current vehicle ownership levels.
The BAU assumes that the Green Line Extension will meet its expected 45,000 daily riders by 2030 (https://www.mass.gov/info-details/about-the-green-line-extension-project), that 100% of these are round trips and 57% are Somerville residents (based on current commute patterns: https://onthemap.ces.census.gov/), meaning 12,825 individual residents of Somerville are riding the Green Line daily. Assuming these represent 12,825 separate households, the BAU then assumes that about 37% of these households would have been driving instead, based on current commute

density, from a projected 0.1% annual rate of population growth based on historical trends. Lastly, the BAU assumes economy-wide emissions reductions trends continue at historic rates of 1% per year for goods and services, including food.

With these existing policies and moderate assumptions about future household characteristics, Somerville can expect emissions to decrease, largely due to existing policies enacted by the City and the Commonwealth. Under a business-as-usual approach, Somerville can expect to see average per-household consumption-based emissions decline from the current levels of 33 $MTCO_2e$ per household to about 28 $MTCO_2e$ per household in 2030 and 21 $MTCO_2e$ per household by 2050. The largest reductions occur in emissions from transportation, followed by food and services.

Table 3. Business-as-Usual Projections

Category	2014	2019	2030	2050	Total Reduction (2014-2050)	% change (2014-2050)
Total	**30.4**	**33.3**	**27.7**	**21.1**	**-9.3**	**-31%**
Food	7.2	8.2	7.2	5.9	-1.3	-18%
Transportation	7.0	8.0	5.8	2.7	-4.3	-61%
Services	6.5	7.1	6.2	5.1	-1.4	-22%
Housing	5.8	5.3	4.3	4.0	-1.7	-30%
Goods	3.9	4.7	4.1	3.4	-0.6	-14%

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mode shares, and that those households then reduce vehicle ownership by one vehicle. This translates to a reduction of about 4,745 vehicles.

The Bicycle Network Plan also sets a goal of doubling the share of households biking to work to 15% by 2050, from 7.5% in 2019. Assuming linear progress, bicycle commuting can be expected to reach 10% by 2030. Using similar assumptions, the BAU assumes that 37% of the new bike commuters would have been driving, and they reduce vehicle ownership by one vehicle, reducing by another ~505 vehicles, for a total reduction of 5,250 vehicles and reaching roughly 1.0 vehicles per household average citywide.

As of 2019, there are roughly 37,580 vehicles registered in Somerville. At 1.0 vehicles per household, this would decline to about 32,475. For households that own one or more vehicles, the average number of vehicles owned is 1.53. 41% of vehicle-owning households own two or more vehicles, for a total of 23,050 vehicles. Reducing this by 5,100 means roughly 22% of households with two or more vehicles would need to reduce vehicle ownership by one, or 14% of all vehicle-owning households would need to reduce vehicle ownership by one. This would increase the percentage of households with no automobiles to about 30%, which is on par with existing areas of Somerville that are close to the Green Line.

Policy Analysis

To reduce the city's consumption-based emissions further, a set of 15 policies across three different categories were analyzed for their ability to potentially influence emissions, either directly or indirectly. The three categories of analysis were building energy use, transportation and land use planning, and food policy.

Based on this set of policies, seven different possible effects were modeled. Table 4 lists the policies that were analyzed and the associated outcome that was modeled for CBEI reductions. Full details on the policies follow Table 4. For a complete list of policies that were considered for analysis, see Appendix B.

Table 4. CBEI Policies Analyzed

Policies for Analysis	Assumed Outcomes
Building Energy Use Policies	
Require all new construction to be all-electric. Require energy disclosure at point of rent and sale; require electrification at point of major retrofit and sale.	Reduce household natural gas and fuel oil use, beginning with a low-uptake program. By 2030, move to a full phase-out curve, reaching net-zero emissions by 2050.
Require newly opened restaurants to be all-electric in their operations.	Reduce the building energy usage component of restaurant emissions by 5% per year, beginning in 2030.
Require newly opened medical offices and healthcare to be all-electric in their operations, with accommodations made for emergency backup generators.	Reduce the building energy usage component of healthcare emissions by 5% per year, beginning in 2030.

<table>
<tr><th>Policies for Analysis</th><th>Assumed Outcomes</th></tr>
<tr><td colspan="2">Transportation and Land Use Policies</td></tr>
<tr><td>Increase height limits, permitted building envelope, and allowable density in existing mixed-use and high-density residential zoning districts.

Establish by-right approvals and accelerated permit review for affordable housing projects.

Adopt a local density bonus for projects providing additional on-site affordable housing.</td><td>Increase in housing production from 0.1% to 1.15% per year by 2025.</td></tr>
<tr><td>Eliminate parking minimums and adopt parking maximums citywide for new construction and redevelopment projects (i.e., including outside of the Transit Area).

Adopt impact mitigation requirement on new parking construction to fund road repair and safe walking / biking / transit infrastructure.</td><td>All new households would have only 0.5 vehicles per household, beginning in 2025.</td></tr>
<tr><td>Require EV charging infrastructure in 20-100% of newly constructed parking spaces (depending on land use).

Allow EV charging in public right-of-way and on City-owned parking lots and garages.

Zone for commercial EV charging activities in all zoning districts citywide.</td><td>New vehicles purchased by Somerville residents would include 10% more zero-emission vehicles than the state average.</td></tr>
</table>

Policies for Analysis	Assumed Outcomes
Food Policies	
Partner with and incentivize the School District to switch school lunches to plant-based foods. Switch City procurement to plant-based foods. Require inclusion of, and clear signage around, plant-based options in restaurants and grocery stores.	Reduce consumption of meat and dairy by 20% by 2050.

Building Energy Use Policies

Somerville's carbon net negative goal requires eliminating the use of fossil fuels in buildings. Emissions from fossil fuels burned in buildings (natural gas and fuel oil) make up roughly 40% of emissions within city limits, based on data from Somerville's 2020 community GHG inventory.

From a consumption standpoint, natural gas and fuel oil comprise 8% of the average household's carbon footprint. However, natural gas use also contributes to emissions embodied in the consumption of goods and services, such as food consumed away from home and healthcare.

Four policies were selected for review and analysis to help achieve reductions in emissions associated with building energy use. Three outcomes were modeled:

1) Reducing household natural gas and fuel oil, beginning substantially in 2023 and following a logistic function (S-curve) adoption to 100% in 2050,
2) Reducing the building energy emissions from restaurants by 5% per year beginning in 2030, and
3) Reducing the building energy emissions from healthcare by 5% per year beginning in 2030.

All-electric new construction

In July 2019, the City of Berkeley was the first US city to adopt a ban on natural gas hookups in new buildings.[20] Nearly 100 cities and counties across the country have followed suit.[21] However, in Massachusetts, state law has been found to preempt local jurisdictions from adopting similar bans.

To address this state preemption issue, the Massachusetts legislature adopted Bill H.5060 *An Act Driving Clean Energy And Offshore Wind*, which was signed by Governor Baker on August 11th, 2022.[22] Section 84 of the Act directs the Department of Energy Resources to establish a demonstration project by which cities and towns may adopt ordinances that require new building construction or major renovation projects to be fossil fuel-free, and enforce restrictions and prohibitions on new building construction and major renovation projects that are not fossil fuel-free. The Department is authorized to permit up to 10 jurisdictions to participate in the demonstration project. In August 2022, Somerville City Council and Mayor Ballantyne approved a Home Rule petition for the City of Somerville to apply for participation in the demonstration project.[23]

In addition, in December 2022 the Department of Energy Resources filed final regulations for an updated Stretch Code and a new Specialized Stretch Code.[24] Somerville adopted the Stretch Code, a second-tier energy code above the base energy code, in June 2011. The new Specialized Code is a third-tier energy code. The new code will create more stringent requirements for new construction buildings. Mayor Ballantyne introduced an order to adopt the Specialized Code to the Somerville City Council on January 12th, 2023.[25] The City Council adopted the ordinance on January 26 and it will go into effect July 1, 2023.

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[20] Berkeleyside, https://www.berkeleyside.org/2019/07/17/natural-gas-pipes-now-banned-in-new-berkeley-buildings-with-some-exceptions

[21] Building Decarb Coalition, https://buildingdecarb.org/zeb-ordinances

[22] Massachusetts Legislature, https://malegislature.gov/Bills/192/H5060/BillHistory

[23] City of Somerville, https://somervillema.legistar.com/LegislationDetail.aspx?ID=5770168&GUID=5FE18807-0C60-4127-9E72-D25A6BAFDFE7

[24] Department of Energy Resources, https://www.mass.gov/info-details/stretch-energy-code-development-2022

[25] City of Somerville, https://somervillema.legistar.com/LegislationDetail.aspx?ID=5990694&GUID=36135F0B-5CE3-47B2-ADC0-7B8A20AA2330&Options=&Search=

Between the new Specialized Code's requirements, and the potential approval of the home rule petition to enable an outright prohibition on new fossil fuel infrastructure, Somerville could see decreasing use of fossil fuels in new construction in the coming years. Future updates to the Stretch and Specialized Codes and participation in the fossil fuel-free ordinance program or similar policies will serve to further ensure new construction does not use fossil fuels.

Achieving all-electric new construction will help avoid future GHG emissions. However, on its own it will do little to reduce existing levels of emissions. To achieve Somerville's net-zero carbon negative goals, requirements for new construction to be all-electric must be paired with 1) policies to phase out fossil fuels in existing buildings (see below), and 2) policies to encourage actual construction of these buildings to replace existing fossil-fueled buildings (see *Transportation and Land Use* section later).

Energy disclosure at point of rent and sale, electrification at major retrofit or sale

Energy disclosure programs aim to help inform new occupants, including renters, owners, and businesses, about the cost of energy associated with a property, adding information to the real estate market, and helping to overcome the "split incentive" problem. The split incentive refers to rental markets where landlords have the ability but little incentive to make building improvements, while tenants have the incentive but no ability.

The Massachusetts Department of Energy Resources (DOER) supports the Home Energy Labeling Information Exchange (HELIX) program, in partnership with the Vermont Public Service Department and other Northeast states, to make US Department of Energy Home Energy Scores available to prospective homeowners through the Multiple Listing Service (MLS).[26] However, the program is voluntary and participation in reporting home energy scores on the MLS has been limited.

The 2018 Somerville Climate Forward plan, the City's first climate action plan, includes a rental registration and energy standard along with an energy disclosure requirement through a rental licensing program. In addition, DOER will be

[26] American Council for an Energy Efficient Economy, State and Local Policy Database: https://database.aceee.org/state/massachusetts

developing a statewide building energy disclosure program, expected to launch by 2025, but it is only required to apply to buildings greater than 20,000 square feet.[27]

Recent research on the effects of mandatory energy efficiency disclosures in housing markets finds that both buyers and sellers (and presumably renters and landlords) have limited awareness of the relative energy efficiency of a property, and that mandatory disclosures improve that awareness and result in pricing changes accordingly.[28] In the academic literature available, this is primarily found to result in a change in the market price, with more efficient homes being more highly valued and less efficient homes being less valued. However, there is limited research as to what extent energy disclosures at point of sale or rent are effective in driving improvements in energy efficiency. Most research available finds that mandatory disclosures do result in a pricing effect, with more efficient properties being more highly valued by renters[29] and buyers[28], but it is unclear whether this pricing effect has been significant enough to drive sellers and landlords to make improvements.

However, electrification mandates at point of sale or major renovation can have significant impacts. With the average length of home ownership at 14 years in the Boston metro area,[30] and with rental units typically renovated every 15-20 years, adopting a requirement to retrofit at point of sale or renovation beginning in 2030 could ensure decarbonization of virtually every property in Somerville by 2050.

At present, however, such a requirement is preempted by Massachusetts state law. If the home rule petition is approved for the fossil-free demonstration project enabled by H.5060, however, Somerville could be among the first cities in the state to enact a ban on fossil fuels in major renovation projects. Otherwise, the city should advocate for further changes to state law and develop incentive-based programs that are successful in driving voluntary building decarbonization.

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[27] Law & The Environment, "Massachusetts to Require Disclosure of Energy Usage from Large Buildings": https://www.lawandenvironment.com/2022/08/24/massachusetts-to-require-disclosure-of-energy-usage-from-large-buildings/

[28] Myers et al., National Bureau of Economic Research, "Effects of Mandatory Energy Efficiency Disclosure in Housing Markets" (2019): https://www.nber.org/system/files/working_papers/w26436/w26436.pdf

[29] Sussman, R et al. American Council for Energy Efficiency, "Energy Labels Affect Behavior on Rental Listing Websites: A Controlled Experiment" (2022): https://www.aceee.org/research-report/b2204

[30] Ruby Home, https://www.rubyhome.com/blog/average-length-homeownership/

Require newly opened restaurants to be all-electric

While current Massachusetts state law restricts building or energy code regulations that prohibit the use of fossil fuels for communities not participating in the fossil fuel free demonstration program, Somerville may be able to set standards for specific business use cases or permitting requirements. In the case of restaurants, natural gas appliances pose health and safety risks as they are responsible for most fires in eating establishments.[31] Somerville should explore policy options in either permitting and/or health and safety regulations that could either strongly discourage or prohibit the use of natural gas in newly permitted restaurants or incentivize and facilitate all-electric alternatives. Somerville could explore health and safety regulations to ban natural gas, and could consider a program to provide deeply subsidized or no-cost induction cooktops for restaurant operators.

At present, no city has adopted strong regulations addressing natural gas usage in restaurants. Many cities that adopted natural gas bans provided carve-outs for commercial cooking, likely because they are not living spaces, and due to concerns about the availability and ease of use of all-electric alternatives. Somerville could take a leadership role in exploring policy opportunities and partnering with the business community to implement strategies, such as by convening business roundtables with stakeholders (including but not limited to property owners, business owners, appliance manufacturers, and developers) to learn more about opportunities and limitations and develop tailored requirements.

Require newly opened healthcare offices to be all-electric with accommodations for emergency generators

Healthcare is a major sub-category of consumption-based emissions. Natural gas use in medical facilities (doctor's and dentist's offices, hospitals, etc.) makes up an estimated 10% of consumption-based emissions from this healthcare sub-category. Working with property owners and tenants to set up all-electric appliances prior to the business or facility opening can help reduce or prevent new expansions of fossil fuel infrastructure and reduce existing emissions as businesses turn over and new ones open in their place. While the energy intensity and ventilation requirements for intensive medical facilities like hospitals may strain or surpass available all-

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31 National Fire Protection Association, "Structure Fires in Eating and Drinking Establishments" https://www.nfpa.org/News-and-Research/Data-research-and-tools/Building-and-Life-Safety/Eating-and-drinking-establishments

electric technologies at present, low-intensity facilities like outpatient clinics, physician and dental offices, and related professional services can likely have some or all their appliance needs met with all-electric options. As costs decline and technology improves, the City can adjust requirements based upon discussions with stakeholders (including property and business owners).

To work within the existing building code, business licenses could be made contingent upon certain all-electric appliances, or be subject to additional fees (e.g., a mitigation fee for the cost of carbon offsets). Alternatively, businesses could be offered incentives and subsidies (going beyond existing approaches) to install all-electric appliances.

Transportation and Land Use Policies

Transportation is the second largest category of emissions in both the consumption-based and geographic inventories. In the CBEI, transportation emissions are predominantly driven by automobile usage and ownership.

Increase height limits, permitted building envelope, and allowable density in existing mixed-use and high-density residential zoning districts

Somerville adopted a new zoning ordinance in 2019. A preliminary analysis of the zoning ordinance suggests that the permitted building envelopes (or zoning envelopes)[32] are likely insufficient to encourage development. Because Somerville is already built out, the zoning envelope must be substantially greater than existing buildings to encourage development. Given the risks, uncertainties, and costs of development, it may not be economically viable for developers to redevelop existing parcels when the zoned capacity is not several times more than the existing floor area.

Much of Somerville's zoning appears to preclude new construction when evaluated with this rule of thumb. For example, many parcels around Davis Square are zoned Mid-Rise 4 (MR4), which allows for up to four stories, but many of the sites are already built out between two to four stories. As a result, the existing zoning envelope is likely insufficient to encourage substantial new construction in these areas.

[32] A zoning envelope is the maximum volume a building could occupy under the zoning ordinance.

In other locations, the zoning ordinance may allow for sufficient height to encourage development, but the height is effectively blocked or precluded by another development standard. For instance, Broadway near Route 28 is zoned Mid-Rise 5 (MR5) for up to five stories and is lined with smaller single- and multi-family homes. However, these parcels abut Neighborhood Residential (NR) districts to the rear, and the MR5 zoning requires a 30-foot rear setback for the fourth and fifth stories when adjacent to NR. Given the smaller lot sizes, this required setback removes most of the available capacity for those upper two floors, effectively setting the zoning at three stories in these areas and precluding any substantive development.

Expanding the permitted zoning envelope could enable substantial new development. Because the average household in Somerville already has much lower consumption-based emissions than households in most US communities, the city could help to avoid substantial GHG emissions elsewhere by making it possible for more people to live in Somerville. While Somerville's community-wide consumption-based emissions would increase with population, those people would have even greater emissions if they lived elsewhere. In addition, while Somerville will need to add more buildings and infrastructure to accommodate increases in population, the housing and infrastructure built in Somerville is much more efficient than average and results in fewer emissions per household. For example, it takes just as much sidewalk to serve a 50-foot-wide parcel with one house as it does to serve a 50-foot-wide parcel with ten apartments – but that sidewalk could be used by many more people. When including sidewalks, roads, power lines, and water infrastructure, along with other services like public transit and waste hauling, building densely is significantly more environmentally friendly than low-density sprawl.

At the same time, expanding housing construction will have additional benefits and is aligned with SomerVision 2040, along with anti-displacement and equity priorities of the community.

Establish by-right approvals and accelerated permit review for affordable housing projects

Zoning envelopes are not the only barrier to new housing. Affordable housing nationwide is often plagued by delays and permitting barriers, even in those areas where it is most desperately needed. "By-right" approval means that projects are granted permits ministerially, or over the counter. By-right projects are not subject to discretionary review. Instead, if they comply with all applicable objective standards (e.g., zoning, building code, etc.), they are automatically approved by staff. In California, state law (Senate Bill 35) requiring ministerial approval for affordable housing within 60-90 days has significantly expedited affordable housing construction, eliminating barriers and delays that could take years and add tens or hundreds of thousands of dollars in cost to these critical community projects.[33]

Maximize affordable housing construction through new development

Three common opportunities for creating more dedicated affordable (below market rate) housing in Somerville include:

- purchasing existing homes and making them deed-restricted;
- building standalone affordable housing projects; and
- requiring private, market-rate multifamily housing developers to provide affordable units.

All three strategies are critical, but due to the lack of multifamily housing development in Somerville, the third strategy is potentially underutilized.

Part of the challenge, perhaps surprisingly, may come from Somerville's existing affordable housing requirements on new development. Currently, Somerville requires new market-rate buildings to set aside 20% of the units as permanently affordable and pay an additional $10/square foot fee toward other affordable housing programs. When compared with other affordable housing policies in expensive areas, like California and the San Francisco Bay Area, this is a more exacting and expensive requirement for developers. While fees and requirements on market-rate developers can result in the construction of additional units, setting these on-site requirements too high can result in driving them out of the market altogether, netting fewer affordable units for the city and driving up housing costs for existing renters.

Somerville should conduct market studies to determine the *production maximizing* level of affordable housing fees and on-site requirements. In California, cities provide an "in-lieu" option for developers to pay their way out of the on-site requirement, allocating these in-lieu funds to standalone affordable housing projects. Developments that do provide on-site units are awarded a density bonus

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Gravel2Gavel, "Assessing SB 35—Success or Failure?" https://www.gravel2gavel.com/assessing-sb-35/

of up to 50%, along with waivers from a limited number of zoning and permitting requirements (such as height or setback limits); Somerville could consider both (or other) approaches to encourage developers to simultaneously build both market-rate and affordable units.

Eliminate parking minimums, impose parking maximums citywide (going beyond Transit Area)

In its 2019 zoning code update, Somerville eliminated parking minimums and adopted parking maximums within a designated Transit Area that covers approximately 70% of the city. There are still significant areas zoned for mixed-use and mid-rise housing that are outside the Transit Area and retain their parking minimums. With the planned Bicycle Network Plan, some alternatives to driving will be available citywide, including biking and walking. This could provide supporting rationale for the City to evaluate an extension of its parking maximums citywide. In doing so, the City should also balance the needs of residents and visitors who cannot take advantage of the biking and pedestrian networks and will still rely on driving as a primary means of travel. Under the new Bicycle Network Plan the City can eliminate parking requirements citywide.

Removing parking minimums and adopting maximums should reduce parking construction, discourage future residents from vehicle ownership, and support communitywide goals of zero severe or fatal injuries from automobile collisions (Vision Zero) and Somerville Climate Forward.

Adopt impact mitigation requirement on new parking construction to fund road repair and safe walking, biking, and transit infrastructure

Somerville has prepared an ambitious Bicycle Network Plan that has the potential to substantially transform mobility within the city, expanding the citywide bicycle network nearly threefold to serve roughly 60% of Somerville's streets.[34] This ambitious plan requires substantial funding. Somerville also has existing policies around complete streets and vision zero, yet many of the projects envisioned in these plans require additional, as-yet-unidentified funding.

An impact mitigation requirement on new parking can serve to doubly advance car-free mobility initiatives. Mitigation fees will discourage voluntary construction of parking spaces, reducing vehicle ownership, and any fees collected can be allocated

[34] City of Somerville, https://voice.somervillema.gov/somerville-bicycle-network-plan

toward safe street initiatives to help encourage alternatives to driving. Such a mitigation fee could be structured in coordination with parking maximums.

Require electric vehicle (EV) charging infrastructure in 20-100% of newly constructed parking spaces (depending on land use)

While reducing vehicle ownership and automobile usage is critical, ultimately, there will always be some people and businesses who need to rely upon a car. Currently, Somerville is lacking in public and private electric vehicle (EV) chargers, and the State does not have robust requirements for EV charging in new construction – at present, only one parking space is required in commercial lots of 15 or more spaces, according to the Alternative Fuels Data Center.[35] H.5060 *An Act Driving Clean Energy And Offshore Wind* (2022) requires the Massachusetts Executive Office of Energy and Environmental Affairs to facilitate an intergovernmental coordinating council to develop and implement an EV charging station deployment plan, to be published by August 11th, 2023.

Because the Stretch and Specialized codes include requirements for EV charging, Somerville may currently face preemption issues in adopting more stringent requirements. However, the EV charging station deployment plan slated for later in 2023 (referenced above) will likely provide an impetus for further changes to state law and funding efforts. Somerville should track progress of the coordinating council and advocate for city priorities to help shape future legislative and state policy efforts.

Allow public EV charging in public right-of-way and on City-owned parking lots and garages

While the City may be restricted in its ability to mandate EV charging in new developments, it likely has greater authority to lease public land under its jurisdiction, such as public right-of-way – streets or sidewalks – or spots at City-owned lots for EV charging infrastructure.

The City can explore issuing an RFP or establishing a permitting process for EV charging providers to own, operate, and maintain EV chargers on City property. In this case, a private operator would install an EV charger on City property and charge fees for public use of the charger. The operator would pay the City for the right to use the public space and potentially for electricity charges, but the City

[35] Department of Energy, https://afdc.energy.gov/laws/all?state=MA#Laws%20and%20Regulations

would be under no obligation or responsibility to maintain or manage the chargers. This can provide a low-risk, revenue-positive approach for the City to support EV charging development.

In addition, another avenue to explore for public charging includes residential curbside charging. Under this model, the City issues permits to private residents and property owners to install, own, maintain, and operate EV chargers in the public right-of-way in front of their property. While this is not a revenue-positive model and can risk conflict among residents, it can help address EV charging access in residential neighborhoods with limited off-street parking.

Zone for commercial EV charging activities in all zoning districts citywide

In addition to supporting EV charging on public right-of-way and potentially requiring it in new developments, Somerville can also encourage EV charging on existing privately owned and operated parking lots. Somerville currently permits DC Fast Charging activities as a "Recharging Station" use in the MR3, MR4, MR5, MR6, HR, CC, CI, CB, and ASMD districts. While electric vehicle charging stations are permitted as accessory structures, their commercial operation is not explicitly allowed.

Zoning to allow commercially operated EV charging in all zoning districts would provide explicit permission for property owners (businesses, landlords, etc.) to either operate or lease existing off-street parking spaces for EV charging as a business. Because of the longer dwell times currently required for EV charging, zoning to allow for commercial EV charging operation in all districts citywide can be done with limited risk of increasing traffic or congestion in certain neighborhoods. Allowing commercial EV charging operations could also encourage apartment building owners to set up commercial charging stations in residential neighborhoods or help businesses with excess parking spaces lease their spots to a private EV charging operator.

Food Policies

Food is the single largest category of consumption-based emissions. Emissions from food result from three general supply chain stages:

- fertilizer to grow plants,
- emissions associated with food lost as waste, and
- emissions from livestock.

Because all modern food production involves emissions, some emissions are unavoidable. Individual choices, and city policies to encourage behavior changes, can shift consumption to less emissions-intensive options. Meat and dairy products are both the most carbon-intensive foods, as well as the most carbon-intensive goods that can be purchased. Shifting diets to plant-based alternatives can be both a healthier and more environmentally sustainable option.

Switch City procurement to plant-based foods

Somerville can leverage its own procurement to require vendors that contract with the City to offer standard plant-based alternatives, expanding access to and visibility of low-emission foods.

The primary focus is not on directly avoided emissions, because the direct effect on emissions is likely small – especially when compared to the community-wide consumption-based emissions as a whole. Instead, the primary objective would be to increase familiarity, awareness, and comfort with plant-based alternatives. Portugal requires all public schools, cafeterias, universities, hospitals, prisons, and other public buildings to serve at least one plant-based option for every meal.[36]

Partner with and incentivize Somerville Public Schools to switch school lunches to plant-based foods

The direct avoided emissions impact of this policy was not evaluated. The primary objective of a plant-based school lunch program could be to educate and highlight plant-based options for children. Building familiarity and comfort with plant-based foods from a young age can set people up for a lifetime of healthy eating and can also help to influence the behaviors of parents and other family members.

The City can work with Somerville Public Schools to explore opportunities to support plant-based meals, identify suppliers and vendors, and partner on procurement to help achieve greater economies of scale.

[36] Hunter College New York City Food Policy Center, "Vegan Menu Option Requirement, Portugal: Urban Food Policy Snapshot" https://www.nycfoodpolicy.org/vegan-menu-option-requirement-portugal-urban-food-policy-snapshot/

Require inclusion of, and clear signage around, plant-based options in restaurants and grocery stores

Expanding awareness of plant-based options will likely require increased visibility of available options. Presently, several standard vegan- or vegetarian-friendly logos are in use, but may not be familiar to most residents, and may not be applied consistently. Many restaurants and stores do not provide clear signage indicating plant-based options.

Requiring signage and visibility can help shift behaviors.[37] To minimize the impacts to businesses, the requirement can be adopted with a long phase-in time, to allow for signs and menus to be replaced with new options on their ordinary replacement schedule, instead of requiring an additional outlay from businesses.

Policy Scenarios Analysis

Based on the policies of interest, outlined in the previous section, seven potential outcomes of these policies were analyzed for their effect on consumption-based emissions. The policy outcomes were modeled as follows:

1. **Reduce household natural gas and fuel oil usage to 0 by 2050**.

   This policy outcome was modeled with reductions beginning in 2024 through a voluntary decarbonization program, assuming ~0.1% annual uptake rate, until 2030. Beginning in 2030, the policy was modeled as a mandatory program, following a standard logistic (S-curve) function, with 50% decarbonization by 2040 and 100% by 2050.

2. **Increase housing production to 1.15%**

   Growth in housing was modeled as a 0.1% annual increase in the number of households from 2020-2024, and an annual 1.15% increase beginning in 2025. Increases in the number of households was used to calculate changes in worker density and housing density (holding workers per household and vacant home rates constant). These changes in density were used to

[37] Roy, Rajshri et al., Journal of the Academy of Nutrition and Dietetics, "Food Environment Interventions to Improve the Dietary Behavior of Young Adults in Tertiary Education Settings: A Systematic Literature Review" (2015): https://www.sciencedirect.com/science/article/abs/pii/S2212267215011144

calculate changes in vehicle miles traveled (VMT) per household under reduced vehicle ownership and increased EV uptake scenarios.

Somerville households were also compared with households of identical incomes, household sizes, and educational attainment in Middlesex County, Massachusetts, and the US, using changes in home ownership, vehicle ownership, and home sizes in those geographies. All other characteristics, including density, were held constant. Differences in household emissions by location were evaluated for 2019 and found to be roughly 6 tons per household when compared with either Middlesex County, Massachusetts, or US averages. Total effects were calculated assuming two-thirds of the difference in emissions (4 tons) was due to differences in energy and fuel economy that declined to 0 by 2050, with the remaining ~2 tons due to a 10% difference in the consumption of food, goods, and services. The aggregate emission effect from new housing was calculated based on the avoided emissions for the number of additional households (above BAU) in each year and divided by total households.

3. **Reduce meat and dairy consumption by 20% by 2050**

   Meat and dairy consumption were modeled as linearly decreasing by 1% per year from 2030-2050.

4. **Reduce building energy (natural gas) emissions from restaurants by 5% per year from 2030-2050**

   This policy was modeled as a linear reduction in dining out emissions, increasing by 5% each year. Based upon data from the CoolClimate Business Calculator, building energy emissions were estimated at 20% of total restaurant emissions, and so at maximum implementation in 2050, emissions from dining out were reduced by 20%. This estimation was also compared with data from the Energy Information Agency's (EIA's) Commercial Building Energy Consumption Survey (CBECS) and the US Economic Census, to get estimates of natural gas usage for food and hospitality businesses per employee (using national averages) and the number of food and hospitality employees working in Somerville. The CoolClimate Business Calculator and CBECS approach found similar results, and both are included in the results.

5. **Reduce building energy (natural gas) emissions from healthcare by 5% per year from 2030-2050**

   Following the same approach as described above, this policy was modeled as a linear reduction in the natural gas component of healthcare emissions, increasing 5% per year. Based on data from the CoolClimate Business Calculator, natural gas was estimated at 10% of total healthcare emissions; the CBECS approach was similarly used for comparable results.

6. **Increase Electric Vehicle (EV) uptake by 10% above the Massachusetts statewide average**

   Massachusetts vehicle electrification rate was modeled assuming a 15-year lifespan for all vehicles. In 2022, an estimated 1.5% of all automobiles registered in Massachusetts were electric, based upon data from the Alternative Fuels Data Center[38] and the Federal Highway Administration.[39] Electric vehicles were assumed to start at 6% market share for new vehicles beginning in 2020, based on data from Autos Innovate.[40] For BAU, the share of vehicle sales that were electric were modeled as linearly increasing to 35% by 2026, and subsequently following the ACCII ruling requirements. For the increased uptake scenario, the Massachusetts statewide EV market share was increased by 10%. EV uptake was used to calculate average vehicle fuel economy, assuming no changes to average fuel economy from non-EV vehicles.

7. **Reduce vehicle ownership to 0.5 vehicles per new household**

   Household growth was projected through 2050 using both BAU (0.1%) and accelerated (1.15%) growth rates. Vehicle ownership for existing households was calculated at the BAU rate, moving towards 1.0 vehicles per household by 2030. New households were calculated as adding 0.5 vehicles per household to the aggregate number of vehicles in Somerville, and then the adjusted total vehicles per household was calculated based on the aggregate.

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[38] AFDC, "Electric Vehicle Registrations by State" https://afdc.energy.gov/data/10962
[39] FHWA, "State Motor Vehicle Registrations" https://www.fhwa.dot.gov/policyinformation/statistics/2020/mv1.cfm
[40] Autos Innovate, "Get Connected: Electric Vehicle Quarterly Report (Q4)" https://www.autosinnovate.org/posts/market-report/2021-q4-get-connected-electric-vehicle-report

Vehicles per household in 2050 ranged from 0.99, under the low-growth scenario, to 0.84 under the high-growth alternative.

The application of all these policies to their greatest extent is referred to in the remainder of this report as the “maximum reduction scenario.”

Under the maximum reduction scenario, where all policies are deployed to their fullest extent, Somerville could achieve another 3.8 $MTCO_2e$ in annual reductions, bringing the average household’s emissions down to 17.4 $MTCO_2e$ per household by 2050 – a 43% reduction from a 2014 baseline. Figure 19 illustrates the BAU and maximum reduction scenarios and Table 6 summarizes the corresponding values.

Figure 19. Total Emissions per Household – BAU and Maximum Reduction Scenario

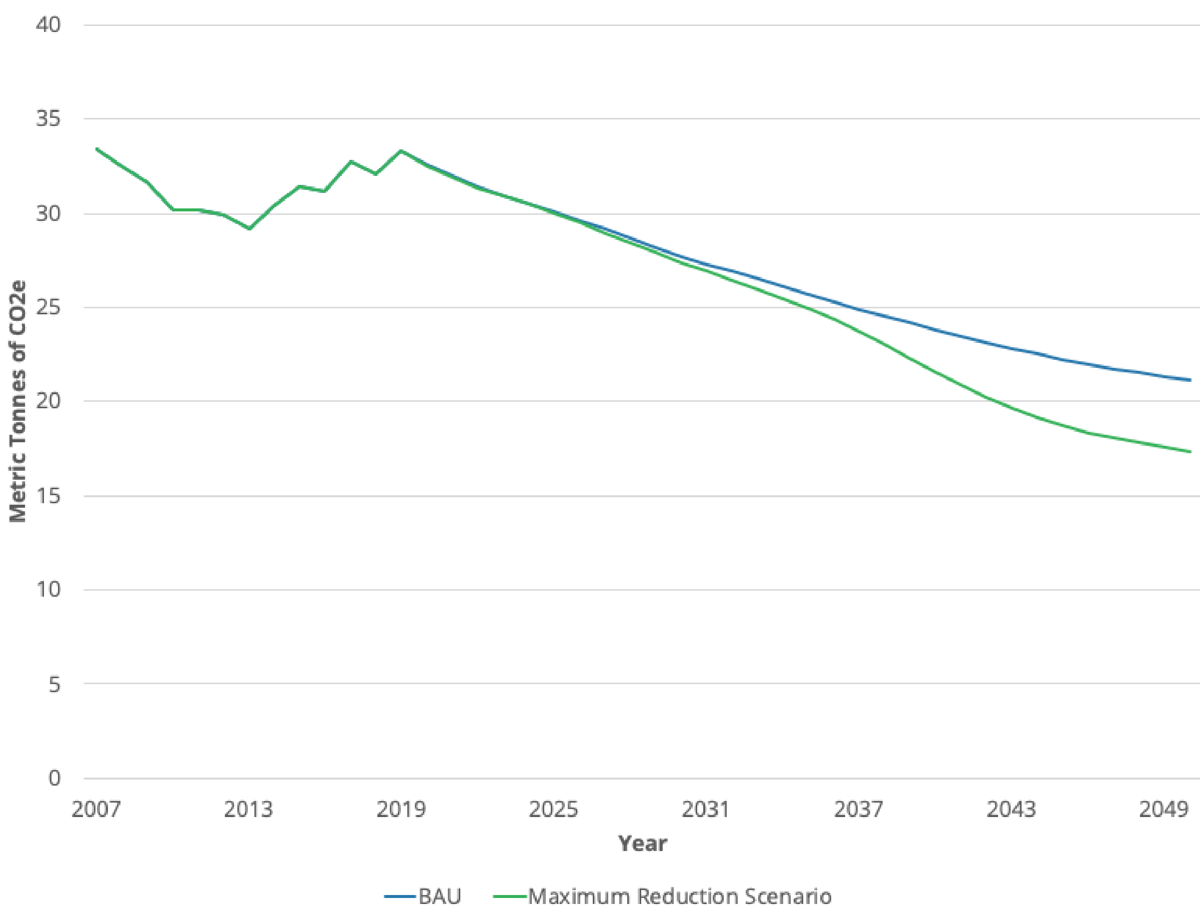


Table 5. Maximum Achievable Reductions vs. BAU Outcomes from Evaluated Policies

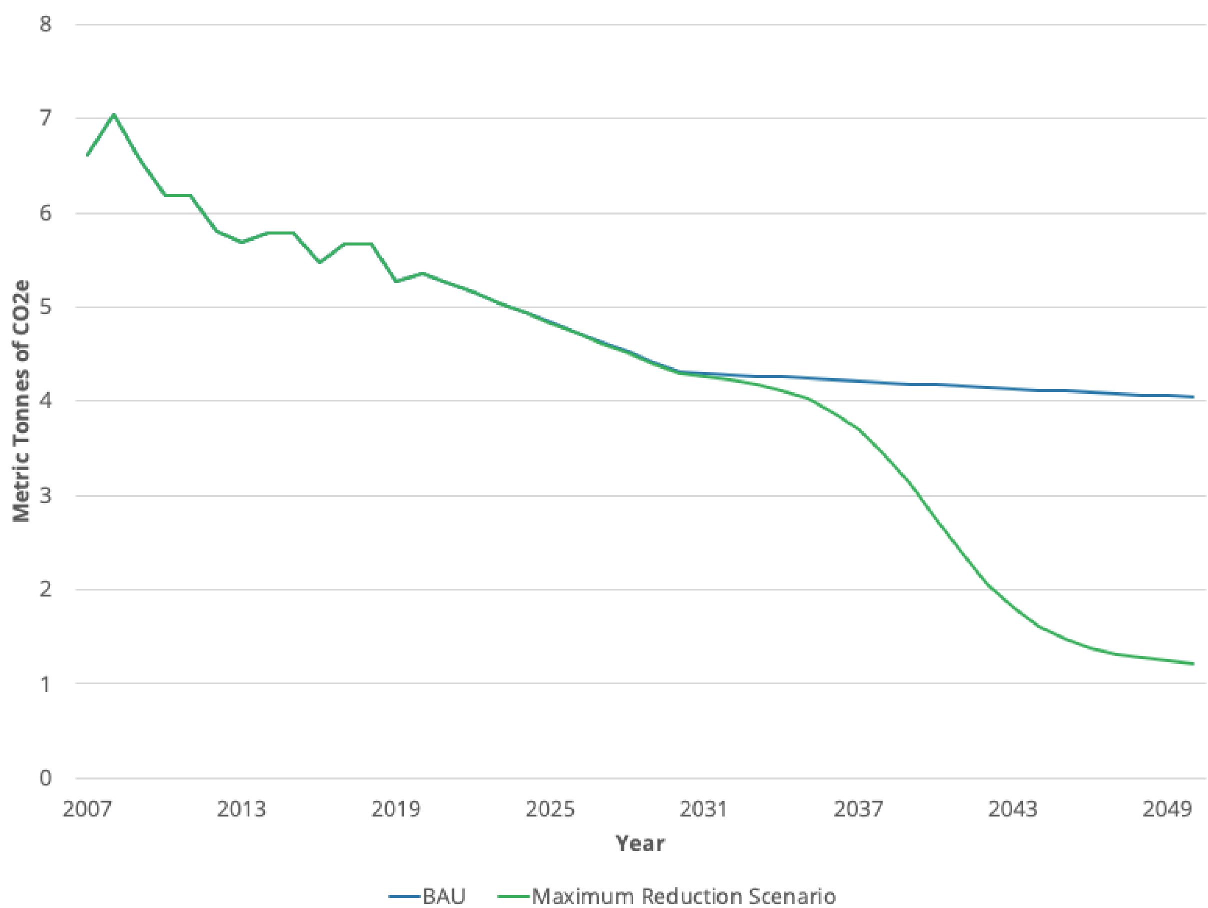
Category	2014	2019	2030	2050	BAU	Maximum	% change

	Baseline year for community GHG inventory	Most recent CBEI analysis year	Interim target year	Target goal year	**Reduction** (2014-2050)	**Reductions** (2014-2050)	(2014-2050)
Total	**30.4**	**33.3**	**27.4**	**17.4**	**-9.3**	**-13.1**	**-43%**
Food	7.2	8.2	7.1	5.2	-1.3	-2.0	-28%
Transportation	7.0	8.0	5.6	2.7	-4.3	-4.3	-61%
Services	6.5	7.1	6.2	4.8	-1.4	-1.7	-26%
Housing	5.8	5.3	4.3	1.2	-1.7	-4.6	-79%
Goods	3.9	4.7	4.1	3.4	-0.6	-0.6	-14%

The additional reductions in 2050 estimated in the maximum reduction scenario come from further reductions in emissions associated with the housing, food, and services categories.

Housing emissions sees the greatest additional decline under the maximum reduction scenario, because of policies on electrifying homes citywide. The S-curve shape of the maximum reduction scenario in Figure 20 reflects the modeled policy adoption rate after 2030.

Figure 20. Housing Emissions per Household – BAU and Maximum Reduction Scenario



For the food and services categories, the reductions are linear, beginning in 2030, based on the evaluated policy outcomes for reducing fossil fuel emissions from restaurants and healthcare, respectively. Figure 21 and Figure 22 illustrate these changes.

Figure 21. Food Emissions per Household – BAU and Maximum Reduction Scenario

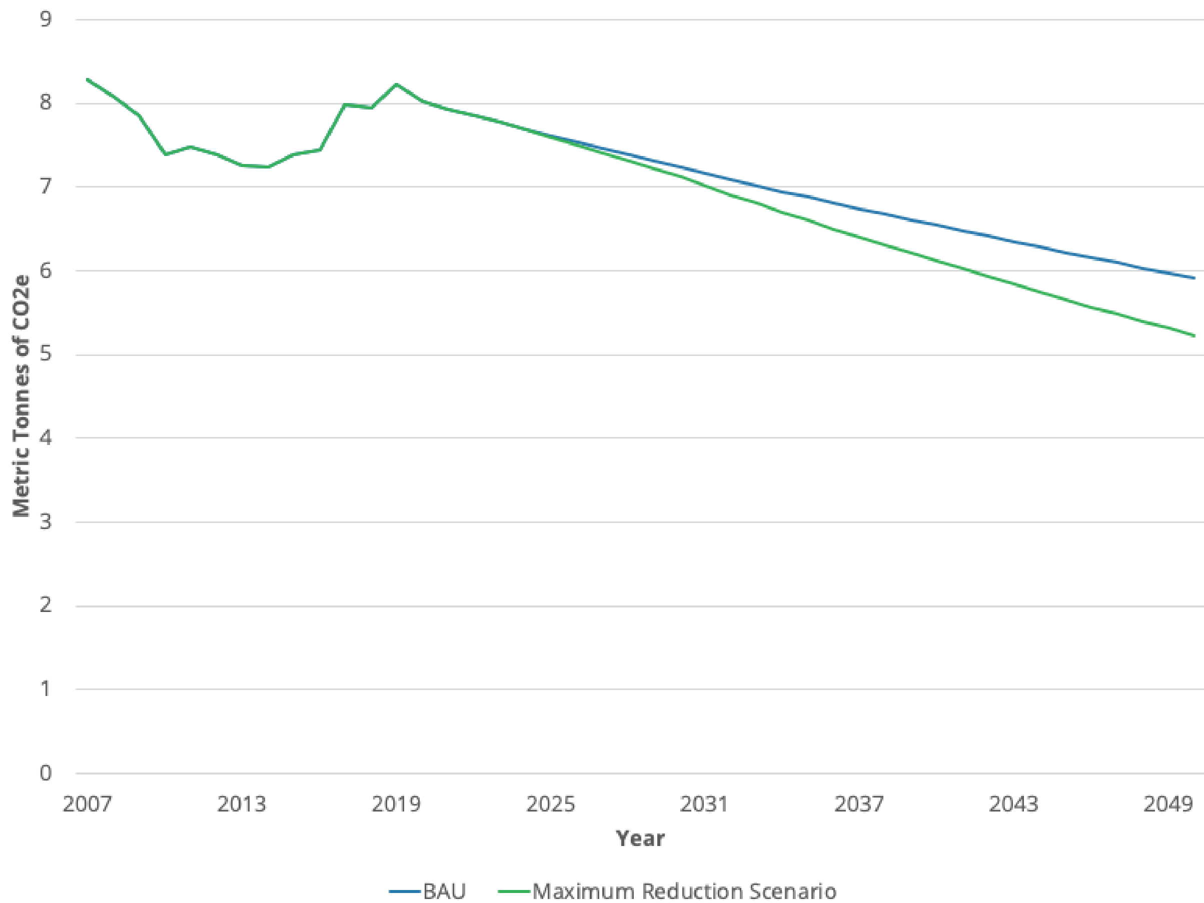
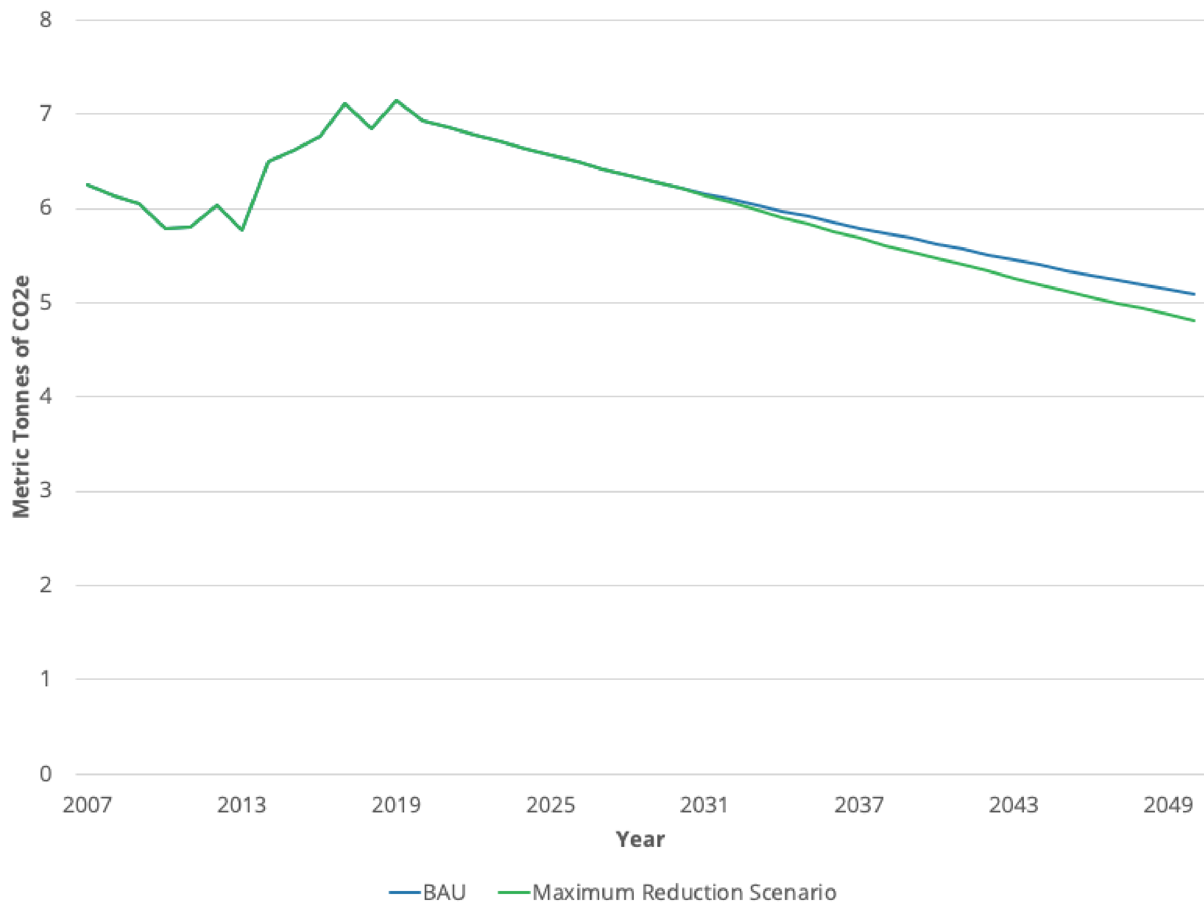
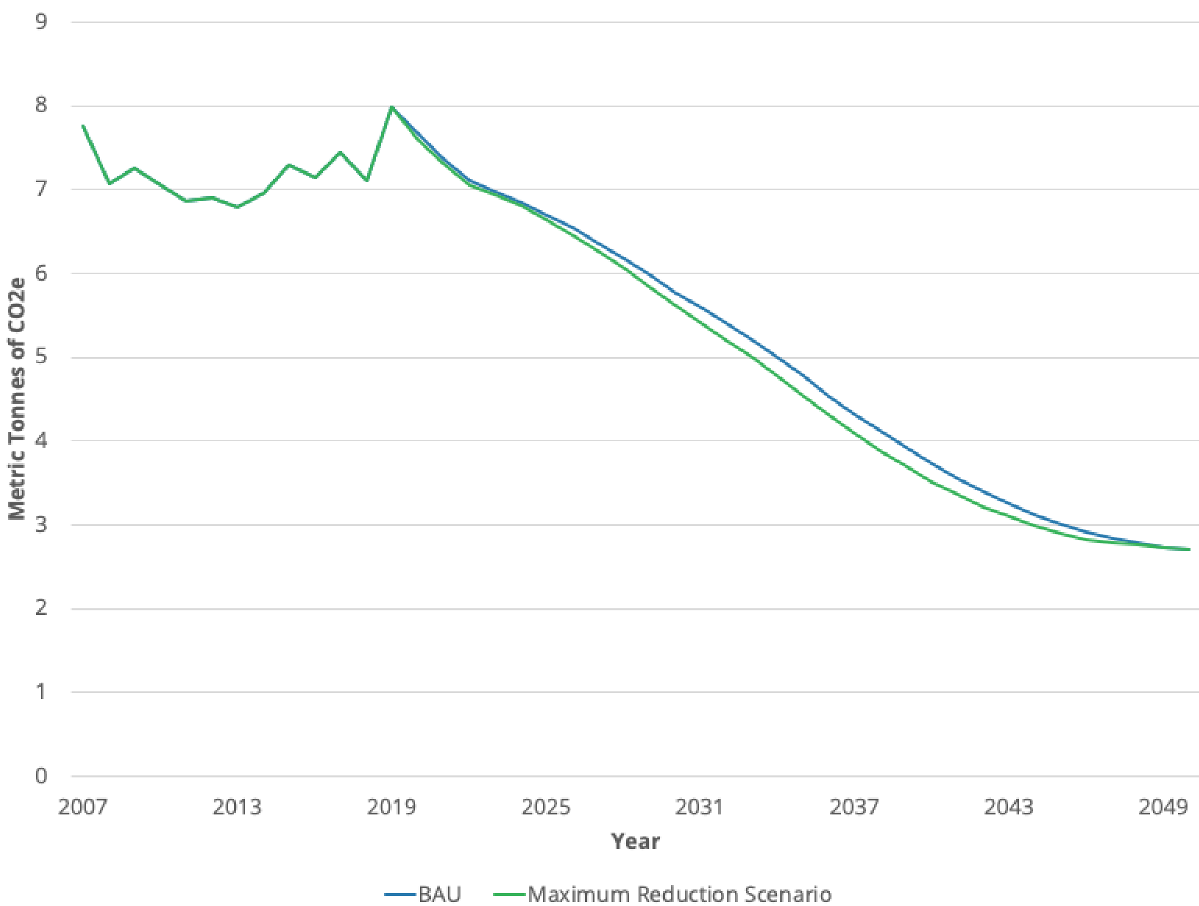


Figure 22. Services Emissions per Household – BAU and Maximum Reduction Scenario



Transportation emissions in 2050 remain constant, because both the BAU and maximum reduction scenarios achieve full decarbonization of automobile usage (due to Massachusetts' adoption of ACCII, the California emission standards that phase out the sale of new combustion vehicles by 2035). However, the pathway to zero emissions changes between the BAU and maximum reduction scenarios (see Figure 23). Under the maximum reduction scenario, Somerville households generate 8.5 fewer $MTCO_2e$ per household over the 25-year period from 2025-2050, compared to the BAU. These aggregate avoided emissions are equivalent to roughly 0.33 additional $MTCO_2e$ avoided each year.

Figure 23. Transportation Emissions per Household – BAU and Maximum Reduction Scenario



Over the 25-year period 2025-2050, the seven modeled policy outcomes were found to have the following total avoided emissions per household:

Table 6. Total Emission Reduction Potential by Policy Outcome

Policy Outcome	25-Year Total Emissions Avoided (Per Household)	Annualized Emission Reductions (average $MTCO_2e$/yr per household)
Reduce household natural gas and fuel oil use to 0 by 2050	29.9 $MTCO_2e$	1.2 $MTCO_2e$/yr
Increase housing construction to 1.15% per year – regionally / nationally avoided emissions	12.3 $MTCO_2e$	0.5 $MTCO_2e$/yr
Combined transportation policies – reduce vehicle ownership for new households, increase EV uptake, and increase housing construction	8.5 $MTCO_2e$	0.3 $MTCO_2e$/yr
Reduce meat and dairy consumption by 20% by 2050	5.7 $MTCO_2e$	0.2 $MTCO_2e$/yr
Increase housing construction to 1.15% per year – transportation impacts	5.5 $MTCO_2e$	0.2 $MTCO_2e$/yr
Reduce the building energy emissions from restaurants by 5% per year	3.3-4.5 $MTCO_2e$	0.1 – 0.2 $MTCO_2e$/yr
Reduce the building energy emissions from healthcare by 5% per year	2.5-3.1 $MTCO_2e$	0.1 $MTCO_2e$/yr
Increase EV uptake by 10% above state average	2.1 $MTCO_2e$	0.1 $MTCO_2e$/yr
Reduce vehicle ownership to 0.5 per household for new households	0.1 $MTCO_2e$	0 $MTCO_2e$/yr

Reducing household natural gas and fuel oil use was found to have the largest impact on emissions by far, avoiding a total of 29.9 $MTCO_2e$ from 2025-2050, or roughly 1.2 $MTCO_2e$ per year on average.

Increasing housing production locally within Somerville had the second largest impact on emissions. Between emissions avoided from residents not living in high-emission neighborhoods outside of Somerville (approximately 12.3 $MTCO_2e$), and emissions avoided from communitywide reductions in automobile usage resulting from increased density (an additional 5.5 $MTCO_2e$), building more housing is projected to avoid 17.8 $MTCO_2e$ per household over 25 years, an average of 0.712 $MTCO_2e$ per year.

When combined with the two other land use and transportation policy outcomes – reducing vehicle ownership and increasing EV uptake – land use and transportation policies could reach as much as 20.8 $MTCO_2e$ avoided per household over a 25-year period.

Reducing meat and dairy consumption is the third largest emissions reduction opportunity, at 5.7 $MTCO_2e$ avoided. However, this is because the emissions reductions from businesses (specifically the dining out and healthcare sub-categories) are split across the two sub-categories. If Somerville chooses to implement policies that affect both dining out and healthcare simultaneously[41], those could have a greater total effect than the achievable reductions from reducing meat and dairy consumption.

Conclusion & Next Steps

Somerville's per-household consumption-based emissions are roughly 33 $MTCO_2e$ annually, well below the national average of 41 $MTCO_2e$. This is largely due to lower-than-average automobile usage, cleaner-than-average electricity provided by Somerville CCE, and a large proportion of renters in the city, living in smaller homes with smaller household sizes.

Under current modeling scenarios, Somerville's maximum potential CBEI reductions by 2050 are 43% of the 2014 baseline per-household emissions, a 12% increase from 31% in the business-as-usual scenario. This is primarily driven by reductions in emissions from buildings due to electrification policies in the maximum reduction scenario. The consumption-based analysis also found strong emission reductions available through shifting to plant-based food alternatives and through increased housing development. Both present new frameworks for evaluating and considering policies, and Somerville should begin working to include both food

[41] For example, if state law changes and Somerville can adopt a requirement to retrofit for all-electric at time of major renovation.

emissions and emissions avoided by welcoming new residents to newly constructed housing, as part of its ongoing sustainability tracking metrics.

The City's existing initiatives around building decarbonization and sustainable transportation will advance both geographic and consumption-based emission reduction goals. While the City has limited ability to directly affect decarbonization of other sectors, such as aviation, food, construction, and imported goods and services, there are still some opportunities for influencing both consumer and supplier behaviors.

Somerville's consumption-based emission reduction goals should aim to push the current expectation of feasibility but should not expect to achieve carbon net negative emissions by 2050. As such, Somerville can aim to achieve a 5% reduction in consumption-based emissions by 2030 and 40% reduction by 2050. This consumption-based emissions reduction goal should be established separately from the City's overall goal.

Appendix A – Methodology

General Overview

The consumption-based emissions inventory (CBEI) is not a direct measurement of individual households' consumption or behavior. Instead, a model (a series of complex calculations) is used to estimate consumption of goods and services and associated emissions. This approach uses a combination of real-world consumption or emissions data, where available, along with predictions based on demographic, regional, and national averages.

Preparing a complete CBEI involves multiple sub-models, but each sub-model follows the same general formula, described below.

1) Select a survey

First, a nationwide survey, conducted by the US federal government, that focuses on an important element of the inventory is selected. The US sub-models are built using the Consumer Expenditures Survey (CEX), the National Household Travel Survey (NHTS), and the Residential Energy Consumption Survey (RECS).

These surveys are used to build the full suite of models for the CBEI. CEX provides data used to model all sub-categories of consumption except for gasoline and home energy use. NHTS provides data for the vehicle miles traveled model, which translates into gasoline usage. RECS provides data for the home energy use models including electricity, natural gas, and other heating fuels.

2) Identify key household characteristics

Next, household characteristics are identified which are both included in the survey and for which nationwide data from the US census and other data sources are available. These data include variables like household size, income, vehicle ownership, etc. Geography, climate, and other relevant data are also included, where applicable.

3) Build a predictive model

With the nationwide survey and selected household and geographic characteristics, a computer program is run to identify how strongly each of those household characteristics correlate with the survey results. This technique is called multiple linear regression and is a type of machine learning. The computer sees many input data (the household and geographic characteristics) and learns how to predict what the outcome will be (the survey result). The computer then provides an equation that takes each of those household and geographic characteristics and produces an estimated result.

A single linear regression might take this form:

$$y = mx + b$$

where y is the survey result (dependent variable), x is the household and geographic characteristics (independent variable), m is the computer's predicted correlation between x and y (slope), and b is a fixed value that adjusts for any underlying base discrepancy between x and y when x is equal to 0 (intercept).

In multiple linear regression, the equation takes on a more complex form:

$$y = m_1x_1 + m_2x_2 + m_3x_3 + \ldots + b$$

where in this case, each x (x_1, x_2, x_3, etc.) is a different household or geographic characteristic, with its own unique correlation (m_1, m_2, m_3, etc.) that together add up to make the overall result. The number of x variables depends on the sub-model and available data. Almost all sub-models use at least six variables ($\ldots x_6$), with some using a dozen or more to get the most accurate prediction possible.

In addition, many of the values considered do not scale linearly. Instead, the models often look more like this:

$$\ln(y) = m_1x_1 + m_2*\ln(x_2) + m_3x_3 + \ldots + b$$

where the survey result might be scaled as a natural log (ln) variable, and some of the household and geographic characteristics are also calculated using its natural log (or sometimes both its ordinary and natural log values). This generally occurs in cases where there are nonlinear effects from household characteristics, and smaller values have different implications than larger values. For example, a household of two is typically two adults, whereas a household of three typically includes a child, which can significantly change consumption patterns. Similarly, consumption patterns based on income change significantly once basic needs are met and "luxury goods" start being consumed.

4) Run the model using local data

After these multivariate logistic regression models are built (see above), local data is then collected to be used in the model. These data consist mostly of census and climate data, from federal sources including the US Census Bureau, the National Oceanic and Atmospheric Administration (NOAA), but also include things like energy prices, inflation rates, fuel economy, and emission factors from sources including the Energy Information Agency (EIA), the Bureau of Labor Statistics (BLS), the Department of Energy (DOE), and the Environmental Protection Agency (EPA). Those values are transformed to fit the required inputs to the model, and then the model is run with that local data as the independent (x) variables in the model.

In some census tracts, local data is a poor fit for the models. Because the models are trained on a limited set of survey data, local outlier values can produce unreasonable results.

For instance, universities can result in unrealistic estimates of things like household size. These significant outliers are corrected to be more realistic estimates of local conditions for typical households in these instances. Extremely wealthy communities (where the average household incomes are well in excess of $300,000/yr) are also an outlier and are adjusted downwards. Much of the luxury spending at these higher income levels is very low-emission due to spending money on intangibles like brand value. For example, luxury clothing and cars have similar emissions as non-luxury goods, but cost significantly more due to the brand, and so adjusting highest-income households downwards preserves the accuracy of the emissions estimates.

5) Calculate emissions

After calculating consumption using the models, emissions are calculated. Most consumption emissions are calculated using the US EPA's US Environmentally Extended Input-Output Model (USEEIO), which bridges the gap between consumption (dollars) and emissions ($MTCO_2e$). This model includes data on emissions by sector and supply chain stage, allowing for differentiation between emissions associated with production, transport, wholesale, and retail, for all US emissions. Emissions associated with fixed capital investments (e.g., buildings and infrastructure construction, excluding residential construction) are also incorporated across all sectors.

Electricity emissions are calculated using EPA’s Emissions and Generation Resource Integrated Database (eGRID) emission factors, detailed at the zip code level and then scaled to any geography. For all other direct consumption of fuels (natural gas / methane, gasoline, etc.), the latest Intergovernmental Panel on Climate Change (IPCC) estimates of global warming potential (GWP) and best available academic literature are used to estimate life-cycle emissions. (IPCC GWP values are commonly used across most emissions reporting protocols, such as the Global Protocol for Community-Scale GHG Inventories and the Local Government Operations Protocol). This includes fugitive emissions (e.g., undesired leaks of greenhouse gases) and non-CO_2 GHG emissions, as well as any additional climate drivers from other emissions (such as particulate matter or contrails).

When working with local jurisdictions, these national or grid average emission factors are replaced with the best available local data. For Somerville, this includes electricity usage and emission factors, as well as water consumption.

6) Make final adjustments to consumption estimates

While the multiple linear regression model helps to estimate consumption, the model does not perfectly resemble reality. These discrepancies are adjusted by comparing the model's predicted results with real-world data wherever available and scaling the model outputs accordingly where real-world data is not available.

To achieve this, the model results are compared with the actual results for the most granular level of data available. This can be national-level data (in the case of surveys), state-level data (in the case of transportation), or locality-level data (in the case of energy or water consumption). For cases where real-world data is available at the geographic scale of interest, the real-world data is used instead; otherwise, the model is run at the same geographic level at which data is available and use that to create a scaling factor, which is used to correct the locally modeled data. For example, modeled state-level energy use is compared with real state-level energy data, and then used to generate a scaling factor to adjust each census tract's modeled energy use. This scaling correction is usually on the order of 10%.

Model Input Variables

The consumption models use the following six variables: household size, average income, vehicle ownership, home ownership, share of household respondents with a bachelor’s degree or higher (educational attainment), and number of rooms (home size).

The vehicle miles traveled model uses household size, average income, vehicle ownership, home ownership, and educational attainment, along with commute time to work, drive alone to work, number of homes per square mile, number of employed people per square mile, employed people per household, family status, children per household, youth per household, adults per household, and Census region.

The home energy models use household size, average income, home ownership, and home size as well as detached home status, heating and cooling degree days, statewide average price of electricity, statewide average price of natural gas, and census division.

Technical Details

The Consumer Expenditures Survey (CEX) is the only annual national survey of household consumption in the United States. Within the CEX, there are a total of 95 categories and sub-categories of expenditures for everything US households consume, including detailed breakdowns of food, utilities, home construction, transportation, household goods and services.

The CEX is used as the initial basis for EcoDataLab's consumption models across all categories of expenditures. Because the smaller sub-categories have more uncertainty and error associated with them, EcoDataLab's models are generally developed at either first- or second-tier category level across the CEX dataset. After running the models at the local level, local consumption estimates are normalized to national data by using a scaling factor based on the ratio of national modeled results to real-world national survey results, across each category of consumption.

CEX categories are then mapped to Personal Consumption Expenditures (PCE) developed by the Bureau of Economic Analysis (BEA). Each PCE maps to one or more sectors of the US economy, and each sector has associated full supply chain emissions available through the US EPA's USEEIO model. BEA's PCE Bridge Tables for 2012 allow for assigning emissions to cradle-to-gate, transportation to market, and trade stages. Custom emission factors (grams CO2e per dollar of expenditure) are then created based on the detailed mapping of sectors, PCE, and CEX categories. This converts average US household expenditures to total US emissions, broken down by each CEX category and in total.

These custom emission factors are then increased to account for embodied emissions in fixed capital investments (buildings and infrastructure). Emissions from fixed capital are attributed to each sector based upon that sector's economic weight. This results in a new, final emission factor (grams CO2e per dollar of CE expenditure) that accounts for all lifecycle emissions associated with that category of expenditure.

However, these lifecycle emission factors based upon USEEIO data are only available for the year 2012. To calculate emissions in other years, they are adjusted backwards and forwards in time as needed using an average decarbonization rate (assumed 1% based on academic literature). Prior to calculating emissions, all modeled and real-world household expenditures are also normalized to 2012 US dollars using the category-specific Consumer Price Index (CPI) for each category.

While the CBEI models started with the CEX, greater accuracy in calculating emissions can be achieved by using other household surveys for specific sub-categories: namely, by using the National Household Travel Survey (NHTS) to model household vehicle miles traveled (VMT), and by using the Residential Energy

Consumption Survey (RECS) to model household energy usage. These models are the most robust models that could be constructed using recent and relevant data, and in many cases are a very strong fit. For instance, at the state level, EcoDataLab's electricity and natural gas models have a goodness of fit R2 value of about 0.87 and 0.72, meaning they explain about 87% and 72% of the variation in household energy use, for their respective categories of energy. When comparing with specific city and county-level data, these modeled results are typically within ~10% of the real-world data, providing sufficient accuracy for historical back-casting and local tract-level estimates of variation.

In preparing consumption-based emissions inventories, CEX-based modeled estimates of expenditures on gasoline, electricity, natural gas, and other fuels are replaced with results from these other sub-models. With these models, direct and indirect (well-to-pump) emission factors are applied for both fossil fuels and electricity consumed directly by households.

Gasoline emissions are based on US national average vehicle fuel economy data from the Department of Transportation. Electricity emission factors are based on US EPA eGRID region emission factors at the zip code level, and scaled to other geographies based on population, unless local emission factors are available (as is the case with Somerville).

Because of the combination of local characteristics to inform regression modeling and scaling based on real-world national data to capture general trends, this methodology allows for consistently tracking changes in the quantity of household consumption over time, and to estimate the impact of consumption on emissions using best-available sources.

As reported in the Consumption-Based Greenhouse Gas Emissions Inventory of San Francisco from 1990 to 2015,[42] this consumption-based approach accounts for essentially all GHG emissions in the US economy but allocated to households and government. Figure 7 in that report shows that the CBEI correlates very closely to the traditional inventory (within 10%). One limitation of this approach is that imports are assumed to be produced with the same carbon intensity as domestic production; future work will likely incorporate a multi-regional input output model (MRIO) (such as Eora or Exiobase3) to account for the carbon intensity of imports.

[42] CoolClimate Network, https://escholarship.org/uc/item/4k19r6z7

MRIO models allow for more granular analysis of trade between geographic regions, including between US counties and with other countries.

Limitations

Unlike other CBEI approaches, this model approach allows for some ability to see the effect of policy and to track changes over time. The current approach offers this improved tracking by including more policy-relevant variables, including home size, household size, home ownership, education, income, population density, and vehicle ownership.

However, local changes in policy, behavior, infrastructure, and technology which might affect consumption or emissions in ways beyond the model variables are not included in the current approach. If a local policy changed consumption patterns or the carbon intensity of products or services consumed, EcoDataLab's model would not be able to monitor this with the current methodology. Additional data could supplement the approach in future studies.

The current approach does not include an estimate of total error. Ideally, each estimate of consumption and emissions would include uncertainty bounds and analysis of error. Potential sources of error include reporting error in household survey day, sampling error, model error, categorization error, and other errors typically associated with input-output models (in this case, the USEEIO). Most of these errors are known and could be propagated through formulas in the study in future research.

The carbon intensity of imported goods is also assumed to be the same as domestically-produced goods. The current model is unable to track the countries of origin of emissions associated with local consumption. This assumption may affect individual products, such as computers, but is unlikely to have a large impact overall since the United States has a large, fairly carbon-intensive production system, with considerable electricity production from coal, similar to many exporting countries. Future studies could incorporate a multi-regional input output model to provide better data on the effect of international supply chains on consumption-based emissions.

Lastly, it is also assumed that price corresponds with "value added" economic activity. If residents of an area purchase higher priced goods, then the methodology will linearly scale emissions up with prices. This scaling is appropriate if higher prices are the result of additional economic activity, such as importing products from abroad, but is problematic when prices are artificially raised, such as for branding purposes. Conversely, cheaper products will result in lower emissions in the model. Generally, it is assumed that price differences average out over thousands of households.

Appendix B – Policies Explored for Analysis

In developing the set of policies for analysis, a wide range of potential ideas and outcomes were explored. Table 7, below, captures the full range of potential policies and associated outcomes that were considered for evaluation.

These policies were reviewed by members of Somerville's Commission on Energy Use and Climate Change and City staff across multiple departments. Feedback was provided, which informed the ultimate selection (by City staff) of the policies and outcomes that were used in the maximum reduction scenario.

Several commissioners noted strong interest and appreciation for housing development and affordable housing policies. Both City staff and commissioners expressed support for policies to reduce and discourage parking, including eliminating parking minimums, adopting parking maximums, and mitigation fees for new parking. In addition, there was strong interest in strategies for reducing the use of fossil fuels in both residential and food service buildings, but uncertainty about what the City could do given preemption issues in state law. Lastly, electric vehicle and food policies were also well-received.

Among both City staff and commissioners, there was disinterest in policies that would have resulted in smaller home sizes, whether through subdividing or encouraging the construction of new small homes, as Somerville already has very few single-family homes and below-average home sizes. City staff and commissioners were also disinterested in policies that would have attempted to address air travel emissions, as it would be very difficult to implement and track the effectiveness.

Lastly, there were also overarching questions around what could be implemented as a policy and what might require a more intensive program, what the equity implications of various policies might be, and how preemption issues could be navigated. Table 7 presents the initial list of policies considered for further analysis.

Table 7. Policies Explored for Analysis

Policy	Assumed Outcome
Implement a Pro-Housing Initiative to ensure Somerville meets its share of regional housing needs: • Conduct market studies, zoning review, and permitting and process reviews to identify and address significant barriers to development. • Increase height limits, permitted building envelope, and allowable density in existing mixed-use and high-density residential zoning districts. • Reduce uncertainty around development by providing objective design standards and ministerial approval for projects that comply with all objective standards and zoning regulations (e.g., following CA's Housing Accountability Act) • Review permitting processes and identify and address barriers to development	No change in household characteristics. Increase in housing production from 0.1% to 1.15% per year. Emissions of average Somerville households will be compared against emissions of households with identical income, household size, and educational attainment elsewhere in the region; globally avoided emissions will be calculated based on increased growth in Somerville versus elsewhere.
Implement a robust Affordable Housing Development Program: • Pass a bond measure for affordable housing. • Establish by-right approvals and accelerated permit review for affordable housing projects. • Adopt a local density bonus for projects providing additional on-site affordable housing	Build 3,614 deed-restricted affordable homes, increasing the share of affordable housing in Somerville from 11% to 20% per the SomerVision 2040 goal. Assuming residents of affordable housing earn 65% of the area median income, reduce the average household income in Somerville proportionately.
Implement a Sustainable Small Homes	New development is an average of 4

Policy	Assumed Outcome
Somerville program – New Construction: • Adjust development fees to incentivize smaller units. • Encourage the creation of ADUs through permit streamlining, fee reductions, and reduced setback / separation requirements.	rooms per home, down from 5.45.
Implement a Sustainable Small Homes Somerville program – Existing Buildings: • Permit subdividing existing homes. • Encourage subdividing existing homes through permit streamlining, fee reductions, and reduced regulatory burden for small landlords.	Convert 25% of Somerville's single-family homes from 6-room units to two 3-room units by 2040.
Implement a Car-Free Somerville program – bicycle safety: • Dedicate funding to fully implement the Bicycle Master Plan.	Double the share of households biking to work (from 7.5% to 15%) and reduce the share of households driving alone to work proportionately (from 37.7% to 30.2%), by 2050. In addition, EcoDataLab would assume that half of the new households biking to work (3.75%) would go car-free.
Implement a Car-Free Somerville program – parking construction: • Eliminate parking minimums and adopt parking maximums citywide (i.e., including outside of the Transit Area). • Adopt impact fees on new parking construction to fund road repair and safe walking / biking / transit infrastructure.	All new households would have only 0.5 vehicles per household.
Require all new construction to be all-electric.	New construction does not use fuel oil or natural gas, uses Somerville's

Policy	Assumed Outcome
	average electricity consumption
Implement a Residential Building Decarbonization Initiative: • Require electrification at point of major retrofit or sale. • Establish a direct install program to facilitate property owners switching to all-electric appliances. • Provide subsides and incentives through Somerville CCE to encourage property owners to go all-electric.	Reduce household natural gas and fuel oil use by 5% per year, reaching zero emissions by 2045.
Through Somerville CCE, convert all residents to 100% zero-emission electricity: • Expand renewable procurement • Switch customers to 100% renewable by default • Lower prices to be competitive with or undercut alternative power plans • Use community engagement and marketing to encourage residents to stay on CCE 100% renewable offering	All households have 0 emissions from electricity beginning in 2025.

Policy	**Assumed Outcome**
Implement an EV Charging Program: • Require EV charging infrastructure in 20-100% of newly constructed parking spaces (depending on land use). • Require EV chargers in 20% of parking stalls at existing parking garages by 2030. • Issue an RFP for commercial EV charging in public right-of-way (e.g., using power poles and lampposts) and on City-owned parking lots and garages. • Permit residential installation of private curbside EV chargers. • Zone for commercial EV charging activities in all zoning districts citywide.	New vehicles purchased by Somerville residents would include 10% more zero-emission vehicles than the state average.
Implement a Restaurant Decarbonization Initiative: • Develop an outreach, education, direct install, and incentive program to help convert existing restaurants to all-electric operations. • Require new restaurants to be all-electric in their operations.	Reduce the building energy usage component of Dining Out emissions by 5% per year, beginning in 2025.
Implement a Healthcare Decarbonization Initiative: • Develop an outreach, education, direct install, and incentive program to help convert existing medical offices and healthcare facilities to all-electric operations. • Require new medical offices and healthcare to be all-electric in their operations.	Reduce the building energy usage component of healthcare emissions by 5% per year, beginning in 2025.
Implement a Plant-Based Foods	Reduce consumption of meat and dairy

Policy	Assumed Outcome
Initiative: • Switch school lunches to plant-based foods. • Switch city procurement to plant-based foods. • Launch an educational, awareness, and marketing campaign to inform and encourage plant-based diets among residents. • Require inclusion of, and clear signage around, plant-based options in restaurants and grocery stores. • Adopt a tax on meat and dairy, dedicating the funding to the Plant-Based Foods Initiative. • Provide subsidies or financial incentives for plant-based foods, potentially including financial incentives for grocery stores and restaurants to reduce sales of meat and dairy.	by 20% by 2050
Implement a Trips on Trains Initiative: • Coordinate with MBTA, Amtrak, and tourism agencies in nearby Amtrak-served destinations to market and promote rail over air travel for short-haul flights • Collaborate with regional and national partners to advocate for and advance high-quality long-distance rail service • Partner with BOS and other stakeholders to reduce the prevalence of short-haul flights	Reduce short-haul air travel by 20% by 2050

Appendix C – Opportunities for Individual Action

There are many opportunities for Somerville residents to reduce their consumption-based emissions through local action. Because the City government has limited authority over consumer choices, residents' personal decisions are an important factor in reducing consumption-based emissions in addition to direct City action. This section lists examples of actions that residents can take to reduce their consumption-based emissions within five major sub-categories.

What Can You Do? – Reduce Gasoline Consumption

Many Somerville households already have low to no emissions from automobile usage. In 2019, 37% of workers drove alone to work. Given Somerville's built environment and transit service, many households can likely further reduce automobile usage by relying further on MBTA services, including the new Green Line extension. The City of Somerville has also recently adopted a Bicycle Network Plan, aiming to expand safe and protected bike lanes throughout the city to further support alternative transit.

For households that aim to reduce their emissions from automobiles but cannot avoid driving, switching their primary commute vehicle to an electric vehicle is a common strategy. Depending on location and use case, some households can purchase one or more electric bicycles (e-bikes) to substitute for an automobile. E-bikes are bicycles that include an electric motor to assist pedaling, and can typically reach speeds of 20-28 mph. Some models include large cargo carriers capable of carrying kids, groceries, or even furniture. As of January 2023, the Commonwealth of Massachusetts is developing an e-bike incentive program to provide point-of-sale rebates for electric bicycles.[43]

Between e-bikes, public transit, and the availability of car-sharing, rentals, or taxis (including Uber and Lyft), some households can achieve significant reductions in automobile usage, or even eliminate their automobile use altogether. Somerville is one of the few places in the US where a car-free lifestyle is readily accessible.

[43] MassBike.org, https://www.massbike.org/ebikebillsupdate_0822

What Can You Do? – Reduce Natural Gas Use

Typically, the most effective ways for households to reduce their natural gas usage is to replace gas furnaces and water heaters with heat pumps, clothes dryers with electric alternatives, and gas cookstoves with induction cooktops. Mass Save offers incentives and rebates to support building decarbonization and enable households to move to clean zero-emission appliances.

Even with financial support, these replacement appliances and associated home electrical upgrades can be expensive, so energy efficiency improvements in the interim can also help reduce natural gas usage.

What Can You Do? – Reduce Food Emissions

Households that aim to reduce emissions from food have two primary strategies they can use. First, avoiding food waste and only buying as much food as the household needs is one of the easiest - and most cost-effective - ways to avoid food emissions. Second, replacing meat and dairy with plant-based substitutes can lead to further large emissions reductions. Buying organic and locally grown food does not typically have much impact on emissions but can provide other social, economic, and/or environmental benefits.

What Can You Do? – Reduce Air Travel

Households that aim to reduce their air travel emissions typically avoid flying, take long-distance buses, or take a train instead when available. Somerville residents have easy access to Boston North and South Stations, where trains offer short trips to locations across New England and the East Coast.

What Can You Do? – Reduce Electricity Emissions

Some common strategies for households to reduce their electricity emissions include energy efficiency improvements and/or switching to 100% carbon-free or renewable electricity.

To improve energy efficiency, households can improve insulation and weatherization, replace old lightbulbs with LEDs and ensure new appliances are ENERGY STAR-certified, and use a smart thermostat to ensure heating and air conditioning only run when needed.

Both Somerville and the Commonwealth of Massachusetts offer incentives and rebates to support energy efficiency, weatherization, electrification, and ENERGY

STAR appliances. Programs and incentives available through the City of Somerville can be combined with resources from Mass Save, MassHousing, Massachusetts Clean Energy Center, and the Department of Energy Resources to provide additional support to income-qualified property owners and renters.

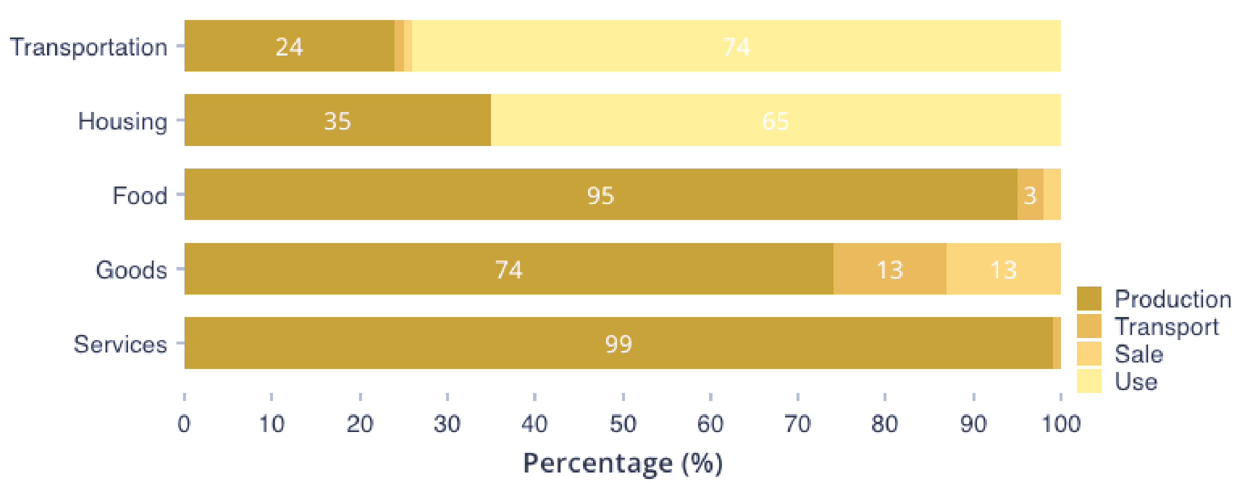
For clean or renewable electricity, Somerville offers Somerville CCE, a local program to provide residents with clean, renewable energy. Somerville CCE offers Somerville Local Green, with 20% more regionally produced, zero carbon renewable energy than the statewide requirement, as well as Somerville 100% Local Green, which offers 100% renewable energy for electric customers. As of January 2023, Somerville's Local Green and 100% Local Green electricity rates are lower than those provided by the investor-owned utility Eversource.

Appendix D – Emissions Breakdown by Supply Chain Stage

Somerville's consumption-based emissions inventory assumes all categories and sub-categories (except electricity) have the same emissions intensity as the US average. This means that the CBEI assumes every dollar spent, mile driven, or unit of energy used for home heating by Somerville residents has the same emissions as the average dollar, mile, or unit of energy spent in the US. (For electricity, a Somerville-specific emissions intensity was used).

The CBEI also assumes those emissions occur in the same places throughout the supply chain. Emissions are generated in production, during transport (by rail, sea, road, or air), in wholesale and retail, and use. In some cases, disposal also generates emissions; however, disposal also sometimes results in storing carbon that would otherwise be re-emitted or avoiding emissions that would result from extraction and processing of raw materials. Figure 24 shows the share of emissions associated with production, transport, sale, and use for each overarching category of goods. Because disposal emissions are sometimes negative, such as from composting or recycling, they are not included on this chart.

Figure 24. Household Emissions Breakdown by Supply Chain Stage – US average

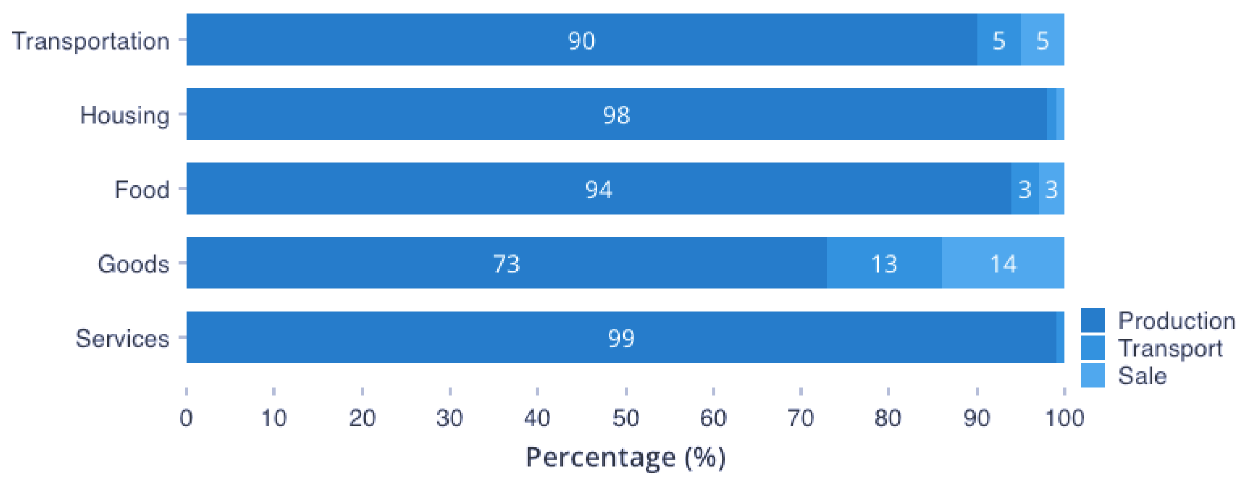


This figure shows, for each category of consumption, the percentage of emissions that are associated with each life-cycle phase (production, transport, sale, and use).

Overall, household emissions from transportation and housing are dominated by "use phase" emissions - the burning of fossil fuels (such as gasoline or the methane in natural gas) for transportation or home heating energy. This "use phase" (primarily gasoline combustion) makes up nearly 74% of household transportation emissions. For housing emissions, "use phase" emissions (electricity and home heating fuels) make up 65%.

For food, goods, and services, use phase emissions are practically zero. These categories have some transport and sale emissions but are overwhelmingly dominated by production emissions. The chart below shows the pre-consumer (production, transport, and sale) breakdown of emissions by category.

Figure 25. Pre-Consumer Emissions Breakdown – US Average



This chart shows, for each category of consumption, what percentage of emissions are associated with each life-cycle phase prior to use (production, transport, and sale). These are the emissions associated with the production of goods and services prior to households acquiring them.

Pre-consumer emissions associated with transportation (that is, prior to a consumer using a vehicle) are predominantly from production (90%). Roughly 50% of these emissions are associated with the production of fuel (oil extraction and refining). The remaining 50% of emissions are from the production of vehicles and vehicle parts. Most of the transport emissions in this section derive from the transport of used vehicles, while sales emissions mostly derive from the sale of gasoline and other transportation fuels.

For housing, over 99% of pre-consumer emissions occur in production. This is dominated by the production of natural gas and the construction of homes, apartments, and other lodging (including hotels). The small portion of these emissions attributable to transport and sale are entirely due to the transport and sale of fossil fuels (and wood) used for home heating.

For food, roughly 95% of emissions occur in production. As discussed in the food breakdown below, food emissions primarily come from application of nitrogen fertilizers and enteric fermentation (methane released from digestion by cows and other livestock). These emissions significantly outweigh the emissions associated with transportation or sale of food.

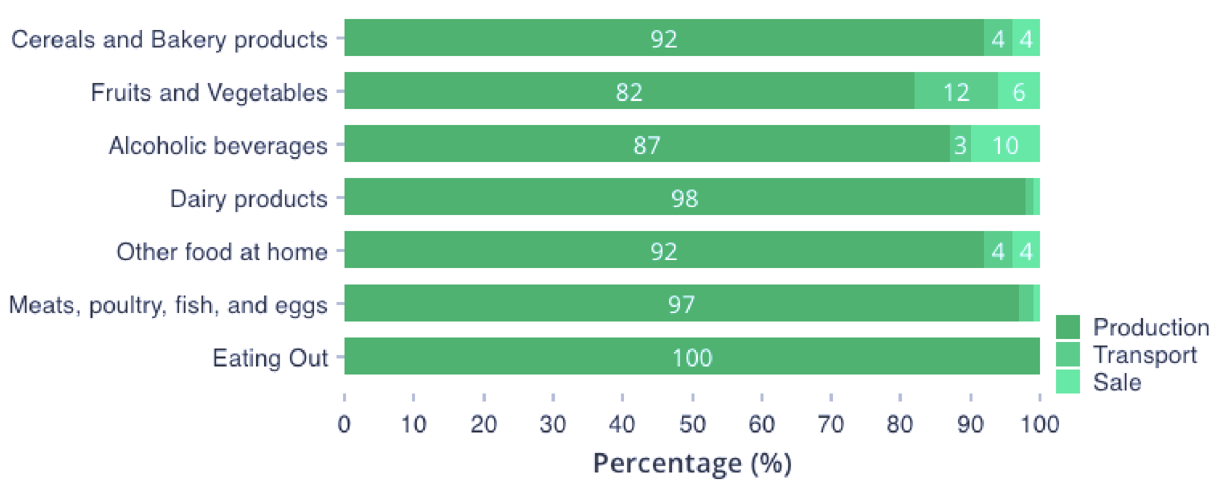
For goods, only about 72% of emissions come from production. About 13% of emissions from goods comes from transportation, and 14% comes from retail. Transport emissions from goods disproportionately occur from truck travel, which make up over 90% of the total goods transport emissions (12% of goods total emissions). Similarly, over 90% of the emissions associated with the sale of goods comes from retail (13% of goods total emissions).

Like housing, pre-consumer emissions from services are overwhelmingly (99%+) from production. Services is primarily made up of activities like healthcare, education, entertainment, and various financial services; most of these involve little to no retail or transportation to provide these services.

Pre-Consumer Food Emissions Breakdown

This chart shows, for each sub-category of food, what percentage of emissions are associated with production, transport, and sale.

Figure 26. Pre-Consumer Food Emissions Breakdown – US Average



For all food sub-categories, over 80% of emissions come from production. For fruits and vegetables, and alcoholic beverages, production emissions account for roughly 83% and 87% of pre-consumer emissions, respectively. Cereals and bakery products, as well as miscellaneous household food (spices, ingredients, etc.), have roughly 92% of their emissions from production. Meanwhile, meat and dairy products have over 97% of their emissions from production, while dining out has 99% of its emissions from production. Within all food sub-categories, transport emissions are overwhelmingly dominated by truck transport.

Meat and dairy products have significantly higher emissions (on both a per calorie and per dollar basis) than other foods. These extra emissions are virtually entirely in the production phase, which is why production is a higher-than-average share of emissions for meat and dairy.

Meanwhile, fruits and vegetables have predominantly production-phase emissions because the transport of food is relatively efficient, even over longer distances. As a result, fruits and vegetables from local farmer's markets are not necessarily lower emissions than those at large supermarkets. Because farmers typically bring relatively small quantities to the farmer's market, the transport may be much less efficient, which could result in a higher overall footprint than food that may have been grown further away but transported more efficiently.

Appendix E – Government Emissions

In the consumption-based emissions inventory, government agencies are considered final demand the same way households are, and so emissions associated with government operations and procurement are not attributed directly to households. However, these emissions are not insignificant – across the US, federal, state, and local governments had emissions totaling over 660 million metric MTCO$_2$e. Of this total, roughly 69% came from state and local governments, with the remaining 31% from the US federal government split between defense (24%) and non-defense sectors (7%).

If these government emissions were allocated to households across the US, it would be an average of 5.5 MTCO$_2$e per household. For Somerville, this would be an additional 176,660 MTCO$_2$e citywide. These are “hidden” emissions that are not otherwise captured in the consumption-based emissions inventory, but still contribute to overall emissions nationally and globally.

Like households, government consumption-based emissions include transportation, buildings, and procurement of goods and services. At the federal level, transportation emissions include the use of military vehicles, aircraft, US Postal Service trucks, and Amtrak trains. State and local governments also operate vehicles which include local public transit trains and buses, police and firefighting vehicles and aircraft, ambulances, roadway repair and maintenance, and more. Because public transit is heavily subsidized in the US and associated emissions are not directly related to consumer spending, these emissions are allocated to government instead.

Government emissions from buildings include natural gas used for heating and water heating, as well as electricity use associated with the operation of the building. Embodied emissions from construction are also included. Government buildings include agency or department offices, legislatures, public colleges and universities, local schools, ports and airports, courts and prisons, post offices, military bases, some museums, research laboratories, libraries, water treatment plants, some hospitals, and more.

Governments spend large sums investing in infrastructure and take on those associated emissions. Roads, highways, and bridges all have large emissions associated with their construction due to the large amounts of asphalt, concrete, and steel used. Governments also build and maintain local water supply and resources, as well as some railway and public transit infrastructure, with additional emissions associated. Lastly, other procurement of a wide variety of materials and services, ranging from office supplies to special firefighting foams, all have emissions associated with them.

Government agencies often have their own internal plans for reducing their emissions with strategies that can include switching to 100% renewable energy, purchasing electric vehicles, and retrofitting buildings to eliminate natural gas usage.

Somerville developed its first local government operations (LGO) inventory in 2014 and has prepared bi-annual updates since then. The inventory follows the Local Government Operations Protocol and includes emissions from municipal facilities, on-road and off-road vehicle fleets, and ice rink refrigerant. The LGO inventory does not include any resident consumption-based emissions but does include some emissions that would be evaluated within a government consumption-based emissions inventory (e.g., building energy and vehicle fuel). As the City is already pursuing a variety of actions that will reduce emissions from their local government operations inventory, they can further lead by example by implementing actions that would also reduce their consumption-based emissions.