Path to Zero Emissions
Creating a Sustainable Carlisle (First Report)

Prepared by:

The Carlisle Energy Task Force

Prepared for:

All who live or work in the Town of Carlisle, Massachusetts

Version 1.0

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Executive Summary

The Carlisle Energy Task Force[1] prepared this report to:

- Help Carlisle residents understand the benefits and implications of adopting and pursuing goals to reduce Carlisle's greenhouse gas emissions
- Help the Master Plan Steering Committee solicit input on the community's level of support for adopting and pursuing emissions reduction goals.

The report documents Carlisle's first community-wide estimate of greenhouse gas emissions (by sector and fuel type), identifies options for greenhouse gas reduction goals, and outlines a conceptual approach for reaching such goals.

2017 Emissions Summary

Figure ES-1 summarizes Carlisle's 2017 direct greenhouse gas emissions.[2] In 2017:

- Residential direct emissions (including vehicles) accounted for about 88% of Carlisle's emissions
- Transportation fuels accounted for about 43% of Carlisle's overall direct emissions.

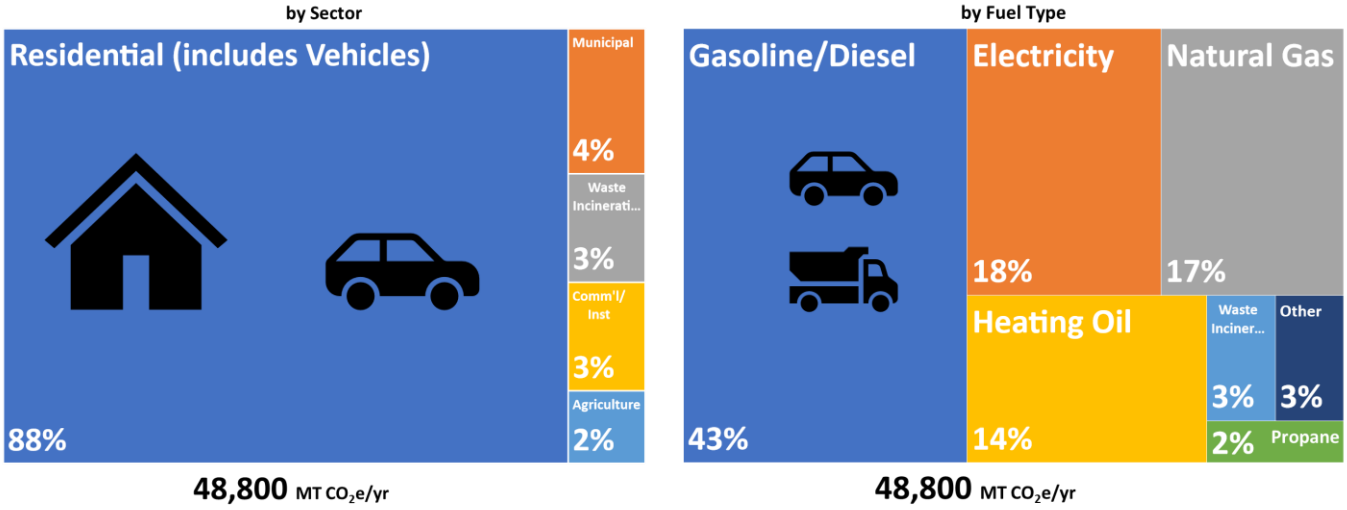

Figure ES-1: Summary of 2017 Greenhouse Gas Emissions for Carlisle

Compared to 1990, we estimate that, through 2017, Carlisle's ***residential energy use*** has increased in proportion to population growth (20% population increase and 18% energy-use increase). During the same period, Carlisle's ***residential greenhouse-gas emissions*** have not increased because the ***emissions*** associated with electricity generation in New England dropped significantly during this time period, translating to 57% lower ***emissions*** per unit of

[1] Prepared by the Sustainability Goals Subcommittee of the Carlisle Energy Task Force, consisting of Robert Zogg and Deborah Bentley, both Carlisle residents.
[2] Emissions are in units of metric tons of carbon-dioxide equivalent per year ($MTCO_2e$/year). A metric ton is about 2,200 pounds, or about 10% more than a U.S. ton.

electricity consumed. These trends do not account for the impacts of Carlisle's switch in July 2018 to a Community Choice Power Supply Program—see discussion below.

Carlisle's per-capita greenhouse gas emissions are over 40% higher than U.S. and Massachusetts averages. Compared to the average Massachusetts resident, the average Carlisle resident:

- Has a home that provides 45% more floor space *per occupant*
- Drives 40% more miles (19.0 vs. 26.5 miles/day/person)
- Has an annual income that is 115% higher.

These factors may in large part explain the higher emissions for Carlisle residents.

The emissions accounted for in Figure ES-1 above represent only about one third of Carlisle's total emissions. Embedded emissions (i.e., emissions associated with the products and services we consume) primarily occur outside of Carlisle, and are difficult to estimate and track. Figure ES-2 shows one estimate of Carlisle's total emissions.

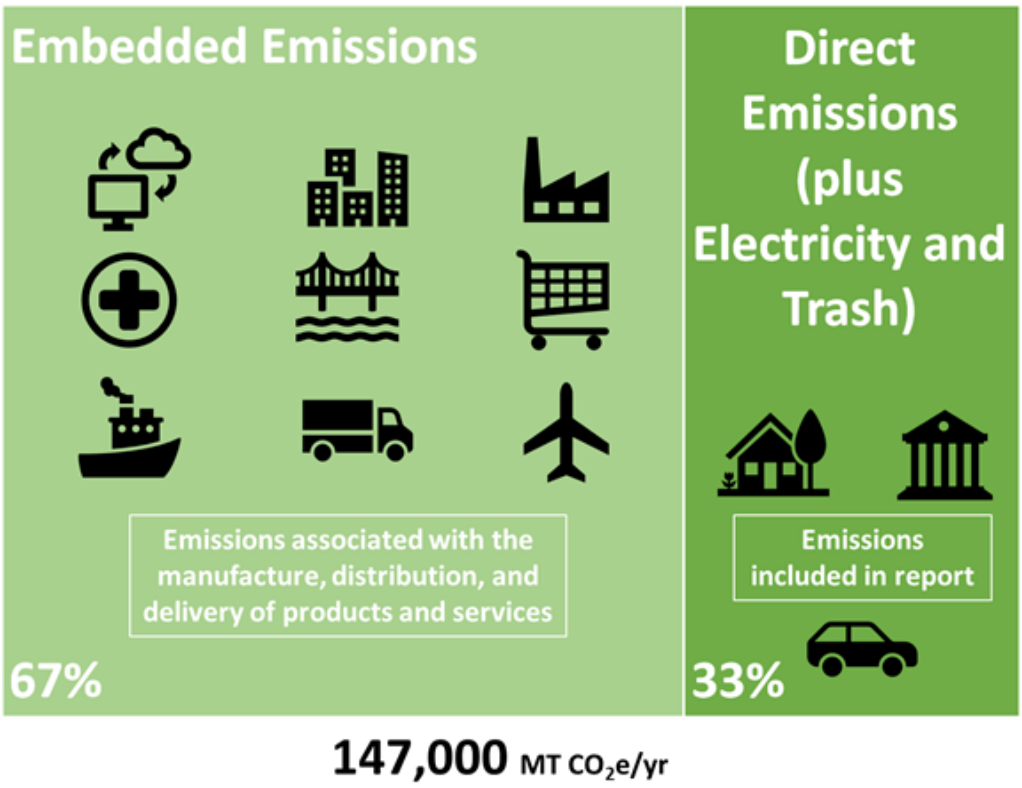

Figure ES-2: 2017 Carlisle Total (Direct and Embedded) Emissions

The impacts of accounting for forest/woodlands sequestration:

- Lower Carlisle total emissions by about 7% compared to a bare-ground alternative
- Increase Carlisle total emissions by about 3% compared to a fully forested alternative.

When comparing Carlisle's emissions to the Massachusetts average, accounting for forest/woodland sequestration has only modest impacts.

Carlisle's Progress to Date

Largely through volunteer efforts (primarily the Carlisle Energy Task Force and also the Carlisle Household Recycling Committee), Carlisle has taken several important steps to lower energy use and reduce greenhouse gas emissions, including:

MA Green Communities Program: From Fiscal 2009 through Fiscal 2019, Carlisle leveraged $788,000 in state funding and utility incentives to lower municipal energy costs by an estimated $120,000/year and municipal greenhouse gas emissions by 22%. As one of the requirements for this program, Carlisle adopted the Stretch Code (780 CMR 115.AA).

Solar Photovoltaics Programs: Through two solar programs, we increased Carlisle's solar generating capacity to about 1,000 kW (1 MW), producing an estimated 1,500 kWh/year, or about 6% of Carlisle's electricity use.

HeatSmart Program: Carlisle led this three-town initiative (with Concord and Lincoln) to promote installations of clean heating and cooling technologies. Under HeatSmart, Carlisle residents installed 11 air-source heat pumps and seven ground-source heat pumps.

Community Choice Power Supply Program: In July of 2018, Carlisle entered into a Community Choice Power Supply program that dramatically increased the amount of renewable electricity purchased in Carlisle. This step alone ***cut Carlisle's electricity emissions by 77% and overall emissions by 14%.***

Community Composting: Carlisle's community composting program reduces our municipal solid waste and, in turn, reduces the Town's incineration fees, GHG emissions associated with waste incineration, and landfill requirements for incinerator ash.

Carlisle continues to work towards additional energy savings and emissions reductions through:

- ***Green Communities:*** Carlisle continues to participate in Massachusetts Green Communities program
- ***Municipal Solar:*** Carlisle is installing a solar canopy at the Carlisle Public School using a third-party owner/operator (see Figure ES-3). Not only will this installation provide renewable electricity, but it is also expected to provide $676,000 in lease payments to the Town over the next 20 years.

- ***Trash Reduction:*** Carlisle is exploring additional options to lower municipal solid waste to reduce costs, greenhouse gas emissions associated with waste incineration, and landfill requirements for incinerator ash.
- ***Carlisle's New Master Plan:*** Carlisle has launched a master plan development process that will address environmental sustainability.

Figure ES-3: Solar Canopies at Carlisle Public School (Summer 2020 Projected Completion)

Options for Emissions-Reduction Goals

Should Carlisle choose to adopt goals to lower greenhouse gas emissions, we identified two logical options:

1. Align with the Massachusetts Global Warming Solutions Act of 2008 (GWSA): Lower town-wide greenhouse gas emissions by 80% by 2050 (1990 baseline) (5% average annual reduction)

2. Align with 2018 recommendations of the Intergovernmental Panel on Climate Change (IPCC): Lower town-wide greenhouse gas emissions by 95% by 2050 (2017 baseline) (10% average annual reduction).

The latter option better reflects what climate scientists estimate is needed globally to limit global warming to 1.5°C and thereby avoid some of the most serious consequences of global climate change. Further, Governor Baker pledged Massachusetts to a new goal of net zero carbon emissions by 2050 at his January 21, 2020 State of the Commonwealth Address.[3] This may lead Massachusetts to update the original GWSA goals.

[3] Transcript available at: https://www.mass.gov/news/governor-baker-delivers-2020-state-of-the-commonwealth-address

Recommended Conceptual Approach

While the GWSA establishes emissions-reduction goals for the state, effectively addressing emissions associated with individuals, small businesses, and municipal operations will likely require local actions and initiatives. Should Carlisle choose to adopt emissions-reduction goals, the most effective approach will likely include:

- Improving the energy efficiency of our homes and buildings
- Electrifying (i.e., converting from fossil fuels to electricity in homes / buildings / vehicles)
- Continuing to switch to renewable electricity
- Sequestering carbon and lowering agricultural emissions, where feasible
- Promoting more sustainable behaviors.

Improving energy efficiency is the most important step in the process of lowering emissions of our homes and buildings. Simply electrifying and using renewable electricity is not sufficient.

To successfully implement this approach, Carlisle will want to:

- Hire a Sustainability Director to manage and promote the process
- Develop energy plans for existing homes and buildings
- Promote electric vehicles
- Promote home/building weatherization, followed by installation of high-efficiency electric appliances and equipment (most importantly, for home/building heating/cooling and domestic water heating)
- Consider regulations and/or permit fees that:
    - Encourage or require new homes and buildings to:
        - Meet passive building standards, or be zero net energy or “zero energy ready”
        - Be electric-vehicle ready
    - Encourage modestly sized living units (using innovative designs to achieve excellent space utilization and aesthetic appeal)
    - Permit multi-family housing on a limited basis, including renovating single-family homes into two-family homes
    - Protect trees and other woody biomass
    - Discourage new uses of fossil fuels
- Establish and maintain accountability for municipal energy use and emissions, and incorporate environmental sustainability into municipal decision-making
- Evaluate and explore new options to purchase and generate renewable electricity
- Promote broad and meaningful community engagement in the process.

Key Benefits

Should the community decide to do so, adopting and pursuing greenhouse gas reduction goals will:

- Help Carlisle residents, businesses, institutions, and municipal departments lower energy costs and reduce environmental impacts
- Improve comfort of homes and buildings
- Improve resiliency to natural disasters of homes and buildings
- Leverage funds from grant programs and utility incentives
- Encourage other communities to pursue similar goals
- Help Massachusetts achieve its emissions reduction goals
- Improve air quality
- Leave a healthier planet for current and future generations.

Key Challenges

A meaningful initiative to pursue emissions reductions will present challenges, including:

- Securing taxpayer investment for a Sustainability Director to develop an implementation plan, pursue grant opportunities, support community initiatives, manage volunteer efforts, and educate the community
- Recruiting adequate community volunteers to assist the Sustainability Director
- Exploring policy changes (such as new bylaws and zoning ordinances) that may be unpopular among some stakeholders
- Motivating Carlisle residents, businesses, institutions, and municipal departments to adopt more sustainable practices.

Next Steps

The key next steps include:

- Broadly vet the idea of setting emissions goals (and the key benefits / implications) through the new master plan development process
- If warranted by the outcome of this vetting process:
    - Incorporate emissions goals into the new master plan, along with a summary of the conceptual approach
    - Present a warrant article at the Annual Town Meeting in 2021 to secure funding for a Sustainability Director
    - Hire a Sustainability Director
    - Develop and execute an implementation plan.

1 Introduction

This section outlines the purpose, scope, terminology, benefits, and disclaimers for this report.

1.1 Purpose

The Carlisle Energy Task Force[4] prepared this report to help Carlisle residents understand the benefits and implications of adopting and pursuing community goals to reduce greenhouse gas (GHG) emissions. In particular, this report provides information to help the Master Plan Steering Committee a) solicit input on the community's level of support for adopting and pursuing emissions reduction goals, and b) incorporate such goals into the new master plan, if appropriate based on community input.[5]

1.2 Scope

This report documents Carlisle's first estimate of community-wide GHG emissions (aka, GHG inventory), including comparisons to Carlisle's 1990 emissions, Massachusetts-average emissions, Concord, MA emissions, and U.S.-average emissions. This report also lists options for GHG emissions reduction goals and a conceptual approach for achieving those goals.

This report focuses primarily on estimating greenhouse gas emissions associated with the direct use of energy in a) Carlisle's residential, municipal, commercial/institutional, and agricultural buildings/grounds, and b) Carlisle's motor vehicles (owned or leased). In addition, we include emissions associated with:

- Livestock and tilled soil
- Generation, transmission, and distribution of electricity
- Leakage of natural gas in the transmission and distribution system
- Municipal waste transport and incineration.

Unless otherwise specified, we do ***not*** include emissions associated with:

- Extraction, processing, and delivery of liquid fuels
- Extraction of natural gas
- Transportation other than the fuel consumption of owned/leased motor vehicles. For example, we exclude emissions from air/boat/rail/bus travel, off-road vehicles, rental vehicles, and for-hire vehicles (such as taxis/Uber/Lyft).[6]
- Federal and state facilities, such as the U.S. postal service and state-operated facilities at Great Brook Farm State Park (although we include emissions from Great Brook Farm that operates in the state park)

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[4] The Carlisle Energy Task Force created the Sustainability Goals Subcommittee to prepare this report. Subcommittee members were Robert Zogg and Deborah Bentley, both Carlisle residents.

[5] Carlisle's Master Plan Steering Committee began meeting in 2018 to prepare a new master plan for Carlisle. At the 2019 Carlisle Town Meeting, residents approved Warrant Article 12, which authorized funding to hire a consulting firm to assist with developing the Master Plan. Carlisle hired a consulting firm in August 2019 to assist with the Master Plan. See: https://www.carlisleplan.org/, https://www.carlislema.gov/779/Master-Plan-Steering-Committee, and https://www.carlisleplan.org/news

[6] Air travel, in particular, has captured much attention in recent years for its carbon-intensity.

- The Greenough Pond and dam.

Further, we do not address other environmental sustainability issues, such as:

- Sustainable water use
- Land preservation/conservation, other than sustainable agricultural practices and forest restoration to sequester GHG emissions
- Adaptation to the effects of climate change (aka, resiliency). While there are opportunities to address resiliency and mitigation simultaneously, improving Carlisle's resiliency will likely require additional measures (such as microgrids, emergency generators, buried electric lines and/or tree removal to protect electric lines, improved emergency shelter facilities and evacuation plans, etc.).

Finally, with few exceptions, we do not document herein the available evidence that human-induced climate change poses a compelling problem that society needs to address. On its website, the National Aeronautics and Space Administration (NASA) provides substantial information about climate change, including evidence, causes, and effects.[7]

1.3 Terminology

We use the terms "carbon emissions", "carbon footprint", "greenhouse gas emissions", "GHG emissions", and "emissions" interchangeably throughout this report. In all cases, we are referring to the human-induced release into the atmosphere of carbon dioxide (CO_2) and other gases that scientists believe contribute to global climate change. Unless otherwise indicated, we use standard units of Metric Tons Carbon Dioxide Equivalent per Year ($MTCO_2e/yr.$), where a metric ton is 1,000 kilograms, or about 2,200 pounds. The term "equivalent" means that emissions of GHG's other than carbon dioxide are converted to weights of carbon dioxide that would have similar global warming impacts.

1.4 Benefits

Should the community decide to do so, adopting and pursuing greenhouse gas reduction goals will:

- Help Carlisle residents, businesses, institutions, and municipal departments lower energy costs and reduce environmental impacts
- Improve comfort of homes and buildings
- Improve resiliency to natural disasters of homes and buildings
- Leverage funds from grant programs and utility incentives
- Encourage other communities to pursue similar goals
- Help Massachusetts achieve its emissions reduction goals
- Improve air quality
- Leave a healthier planet for current and future generations.

[7] Available at: https://climate.nasa.gov/evidence/

1.5 Disclaimers

The steps outlined in the conceptual approach (Section 4) are subject to change should the community decide to adopt and pursue GHG reduction goals.

Emissions estimates presented herein include uncertainties and assumptions. Despite that, in our judgement these estimates are sufficiently accurate for Carlisle residents to understand the implications of adopting and pursuing emissions-reduction goals. Should Carlisle choose to adopt and pursue emissions goals, these estimates should be continually refined and improved.

While existing protocols/guides informed our analysis of Carlisle's energy use and GHG emissions, we did not strictly adhere to any single protocol or guide. One such protocol developed by the GHG Protocol (a partnership between World Resources Institute and the World Business Council for Sustainable Development), suggests a level of rigor that would be difficult for a volunteer team to achieve.[8] Another such guide developed by the Metropolitan Area Planning Council is relatively easy to use, but relies heavily on sources for home/building characteristics that are not community-specific.[9] We blended elements from both these sources, and incorporated some approaches of our own.

The Carlisle Energy Task Force approved this report for publication at its April 1, 2020 meeting.

2 Greenhouse Gas Emissions in Carlisle

Carlisle's greenhouse gas emissions include:

- ***Direct Emissions:*** Emissions associated with the energy we use. We include with direct emissions the emissions associated with:
    - Carlisle's livestock and tilled soil
    - Generation, transmission, and distribution of electricity
    - Municipal waste incineration
    - Leakage of natural gas during transmission and distribution.
- ***Embedded Emissions (aka, Embodied Emissions):*** Emissions associated with the manufacture, distribution, and delivery of products and services.

We focus herein primarily on direct emissions, as defined above, as these are the emissions that we can more readily estimate and track over time. Section 2.1.6 includes an estimate from one source of Carlisle's total (direct and embedded) emissions.

We assign motor-vehicle emissions to the residential, municipal, and commercial/institutional sectors. While transportation-related emissions are often broken out as a separate sector, we

[8] *Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories*; Greenhouse Gas Protocol. Available at: https://ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities

[9] *Estimate Local Energy Use Baseline*; Metropolitan Area Planning Council. We referenced a version that was updated September 21, 2017. As of 06-30-2019, the version posted on line was updated July 3, 2013. Available at: http://www.mapc.org/wp-content/uploads/2017/11/Estimate-Local-Energy-Use-Baseline.pdf

don't follow that convention to give a more complete sense of the emissions associated with each sector.

Sources and assumptions for our emissions estimates, along with calculations, are documented in Attachments 1 to 10.

2.1 Community-Wide Emissions

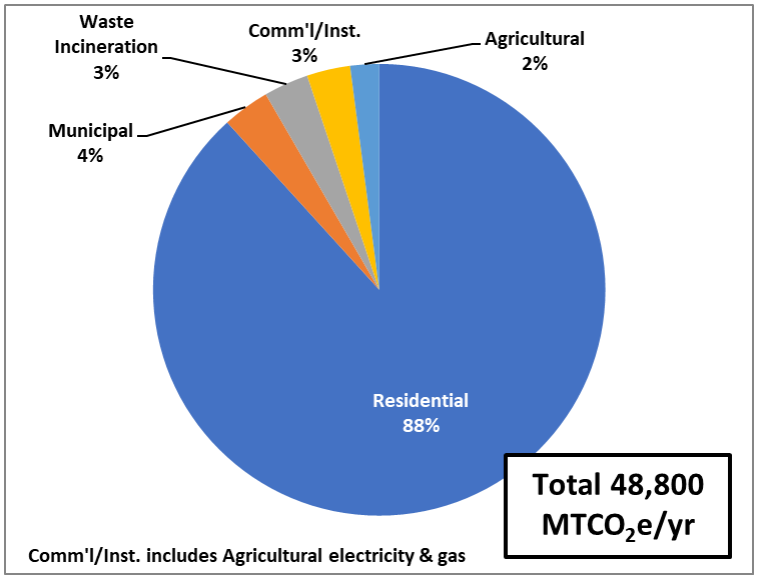


Figure 2-1: 2017 Carlisle Emissions by Sector[10]

Figure 2-1 shows that estimated community-wide direct emissions for 2017 total 48,800 $MTCO_2e/yr$., and indicates that about 88% of our emissions are from the residential sector (including residential vehicles).

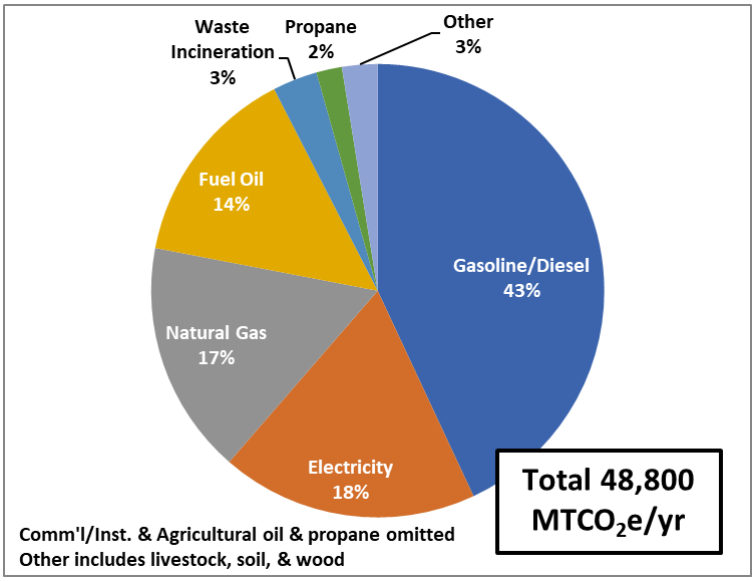


Figure 2-2: 2017 Carlisle Emissions by Fuel Type[11]

Figure 2-2 shows Carlisle's 2017 emissions by fuel type. Transportation fuels (gasoline and Diesel fuel) produce about 43% of Carlisle's emissions. While electricity produced 18% of Carlisle's emissions in 2017, Carlisle's switch to a Community Choice Power Supply program in 2018 lowered electricity-related emissions dramatically. See further discussion in Sections 2.2.6 and 2.3.3.

[10] See sources in subsequent subsections. See data in Attachment 2.
[11] See sources in subsequent subsections. See data in Attachment 2.

2.1.1 Residential Emissions

We obtained data on Carlisle's residential electricity consumption from Eversource, the electric distribution company serving Carlisle. We estimated vehicle emissions based on survey results from the Metropolitan Area Planning Council (MAPC). The MAPC survey, however, did not provide enough information to separate Diesel fuel use from gasoline, so we combined residential Diesel fuel with gasoline—the two fuels have similar greenhouse gas emissions per unit of energy content. We obtained natural-gas consumption data from National Grid.[12] We used those data to estimate emissions from fuel oil and propane, assuming that homes heated by fuel oil and propane have heating loads similar to those heated by natural gas.

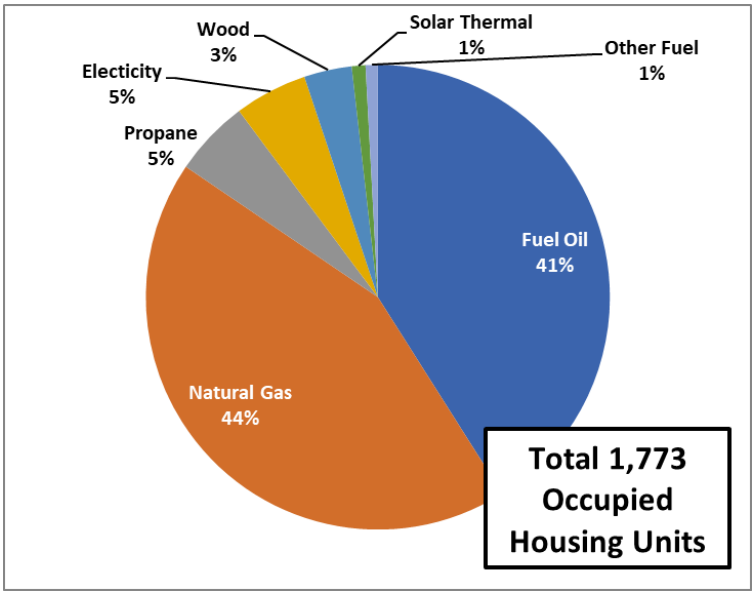


Figure 2-3 shows the estimated breakdown of Carlisle's 2017 housing stock by heating fuel. About 41% of Carlisle homes are heated with fuel oil and about 44% are heated with natural gas. The remaining 15% are heated with propane (about 5%), electricity (about 5%), wood (about 3%), or another source.

Figure 2-3: 2017 Carlisle Occupied Housing Units (by Primary Heating Fuel)[13]

Only about 1% of Carlisle homes are heated with solar energy, although this figure appears to include only homes that use solar thermal home-heating systems, i.e., it appears to exclude homes that generate electricity using solar panels and, in turn, use that electricity for home heating.

[12] 01/02/2020 email from Colette Lamontagne, Director, Innovation Center of Excellence, National Grid, to Bob Zogg. Includes Carlisle natural-gas consumption for 2017 and 2018, broken down by residential and commercial, including number of meters for each.
[13] See Attachment 1 for sources and assumptions

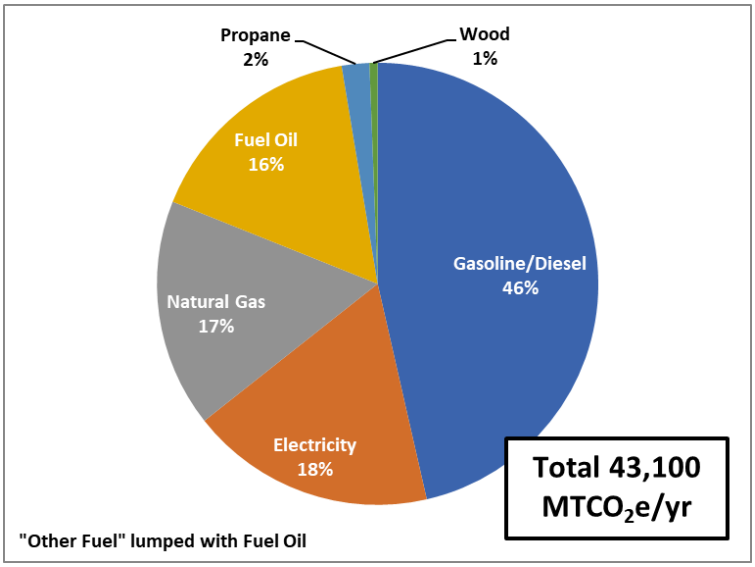


Figure 2-4 shows Carlisle's estimated 2017 residential emissions by fuel type. As the figure shows, motor-vehicle fuel accounts for about 46% of Carlisle's residential emissions. These estimates are prior to Carlisle's July 2018 switch to an alternative electricity supplier (discussed in Section 2.2.6). We discuss the emissions impacts of Carlisle's switch to an alternative electricity supplier in Section 2.3.3.

Figure 2-4: 2017 Carlisle Residential Emissions[14]

2.1.2 Municipal Emissions

We have a good understanding of most of Carlisle's municipal energy use and associated emissions from our involvement in the Massachusetts Green Communities program (discussed in Section 2.2.2). We do not include emissions from federal and state facilities, such as the U.S. postal service and state-operated facilities at Great Brook State Park.

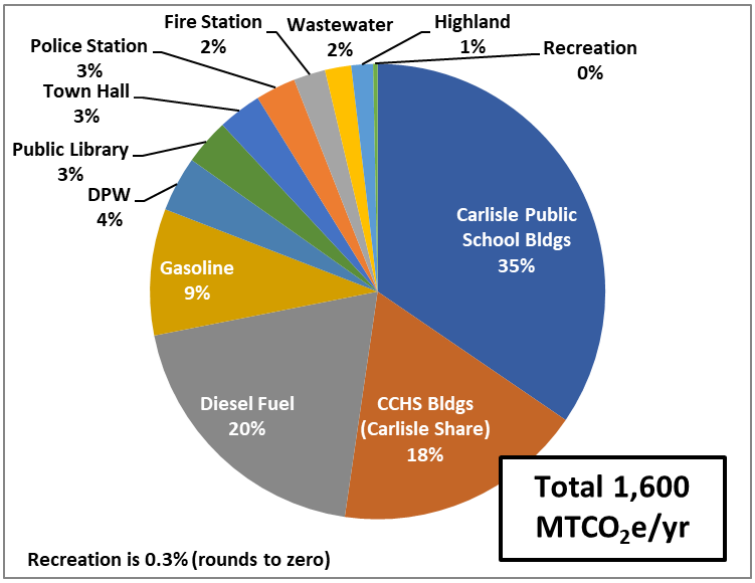
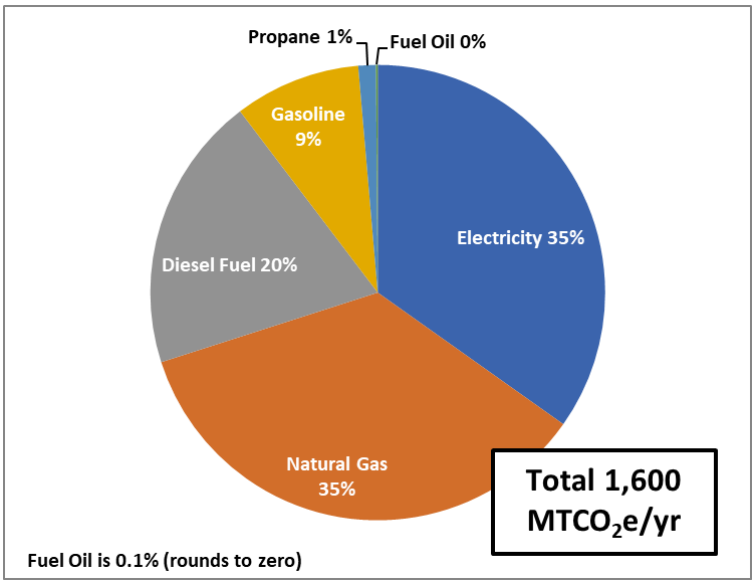


Figure 2-5 and Figure 2-6 show Carlisle's emissions from municipal buildings and vehicles. Carlisle Public School (CPS) buildings account for about 35% of municipal emissions and Carlisle's share (weighted based on student enrollment) of the Concord Carlisle Regional High School (CCHS) buildings account for about 18% of emissions, for a total of about 53% of emissions associated with school buildings. Gasoline and Diesel fuel for all vehicles for all facilities combined account for another 29%

Figure 2-5: 2017 Carlisle Municipal Emissions[15]

[14] See Attachment 1 for sources and assumptions
[15] See Attachments 3 and 4 for sources and assumptions



of emissions.[16] We do not include non-energy-related emissions from the CPS waste treatment facility, but we think those emissions will be very small based on review of other studies.[17] For buildings only (excluding vehicles), 2017 CPS per-student emissions (0.95 $MTCO2_e$/student/year) are about 10% greater than for the CCHS (0.86 $MTCO2_e$/student/year).[18] All remaining municipal buildings combined account for about 18% of municipal emissions.

Figure 2-6: 2017 Carlisle Municipal Emissions by Fuel Type[19]

2.1.3 Emissions from Municipal Waste Incineration

Waste deposited at Carlisle's transfer station, including waste deposited in the trash compactors and items placed in the swap shed that are not taken by residents or recycled, are trucked to a solid-waste incineration plant. In 2016, Carlisle trucked 1,784 tons of trash to this plant.[20] Based on this, we estimate Carlisle's emissions associated with waste incineration are about 1,500 $MTCO_2e$/year.[21, 22] This estimate is based on generic data for waste processing and incineration, rather than data for the specific plant Carlisle uses.

[16] We currently use a rough estimate for CPS school buses. The CPS contracts with an outside service for school buses, so data were not readily available at the time of our analysis.
[17] For example, 2016 greenhouse gas emissions for wastewater treatment in Concord, MA are about 1% of overall emissions. Carlisle's wastewater treatment plant is far smaller than Concord's because Carlisle's plant treats only waste from the CPS, while Concord's plant treats waste from the entire community. See: https://concordma.gov/DocumentCenter/View/19103/Concord-Community-GHG-Inventory-Full-Report--Methodology
[18] See calculations in Attachment 3
[19] See Attachments 3 and 4 for sources and assumptions
[20] Units are short tons (U.S. tons). From von Roesgen, Claude (Carlisle resident); presentation to the Carlisle Energy Task Force on January 2, 2019. Available at: https://www.carlislema.gov/AgendaCenter/ViewFile/Minutes/_01022019-1524
[21] See Attachment 5 for assumptions and sources.
[22] The solid waste incineration plant generates electricity from the heat produced when waste is burned. We did not offset Carlisle's emissions estimate to take credit for this, reasoning that we are still producing the emissions whether or not electricity is generated. The credit might arguably go to the purchasers of the electricity. Had we taken such a credit, the incineration emissions would be reduced by about 15%, assuming that the incinerator electricity offsets electricity generated with the average emissions of New England's electricity grid.

2.1.4 Commercial/Institutional Emissions

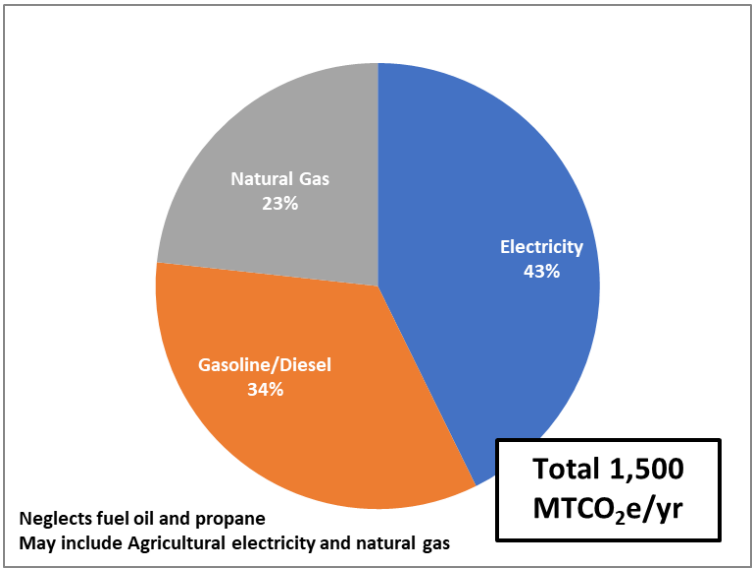


Figure 2-7 shows emissions from Carlisle's commercial and institutional buildings and motor-vehicle fuel (including primarily places of worship and commercial businesses). For the Commercial/Institutional sector, we used electricity and natural-gas consumption data obtained from Eversource and National Grid, respectively. Because these data include municipal consumptions, we subtracted out municipal consumptions before using these data to estimate

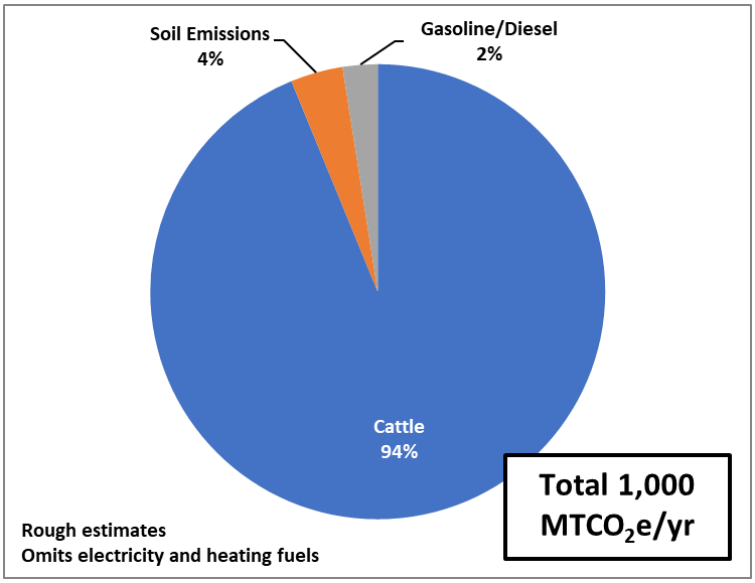
Figure 2-7: 2017 Carlisle Commercial/Institutional Emissions[23]

Commercial/Institutional emissions. Consumption data from Eversource and National Grid do not, however, break out agricultural consumption, so the resulting emissions estimates include emissions associated with electricity and natural-gas consumption in the Agricultural sector. We estimated vehicle emissions, using survey results from the Metropolitan Area Planning Council (MAPC). The MAPC survey, however, did not provide enough information to separate Diesel fuel use from gasoline, so we combined commercial/institutional Diesel fuel with gasoline.

2.1.5 Agricultural Emissions

Studies demonstrate that agriculture generally results in less above-ground (and probably less below-ground) carbon storage compared to natural landscapes.[24] Therefore, most agricultural practices increase atmospheric carbon compared to leaving the land in its natural state. Figure 2-8 shows emissions from Carlisle's agricultural operations, including livestock, tilled soil for crops, and fuel for farm machinery. We neglected agricultural emissions from propane, fuel oil, and wood. Agricultural emissions from natural-gas and electricity are included in the Commercial/Institutional sector..[25] Carlisle's agricultural emissions are dominated by emissions from cattle. We neglected emissions from other livestock.[26]

[23] See Attachment 6 for sources and assumptions
[24] Williams, David R., et.al.; *Carbon Storage and Land-Use Strategies in Agricultural Landscapes across Three Continents*; Current Biology; Volume 28, Issues 15, P2500-2505.E4; August 06, 2018. Available at: https://www.cell.com/current-biology/fulltext/S0960-9822(18)30755-3#%20
[25] Electricity and natural-gas consumption data from Eversource and National Grid, respectively, do not separate agricultural uses from commercial uses.
[26] Other cud-chewing animals such as goats and sheep also emit significant amounts of greenhouse gases, but Carlisle does not have large numbers of goats or sheep.



We obtained assistance from Carlisle's Agricultural Commission to estimate livestock, tilled soil acreage, and farm machinery use in Carlisle.[27] Agricultural emissions estimates are rough at this point because ***emissions estimates for cattle vary by almost a factor of ten*** based on the sources we identified. ***This means that agricultural emissions might actually be as low as 250 or as high as 1,800 MTCO$_2$e/year.***

Figure 2-8: 2017 Carlisle Agricultural Emissions[28]

While we will continue to review and refine these estimates over time, the impacts of these uncertainties on Carlisle's overall emissions will be modest.

2.1.6 Embedded Emissions

Embedded emissions (aka, embodied emissions) are more difficult to estimate and track compared to the direct emissions discussed in the subsections above. As noted above, embedded emissions are the emissions associated with the manufacture, distribution, and delivery of products and services.

Table 2-1 lists examples of Carlisle's embedded emissions.

Table 2-1: Example Sources of Carlisle's Embedded Emission

Example Sources of Carlisle's Embedded Emissions	
Fabrication and delivery of construction materials for homes, commercial/institutional buildings, and industrial plants	Construction of homes, commercial/institutional buildings, and industrial plants
Fabrication and delivery of construction materials for roads, bridges, dams, and other infrastructure	Construction of roads, bridges, dams, and other infrastructure
Air, train, and subway travel	For-hire vehicles
Operation of industrial plants	Other shipping / trucking
Operation of commercial and institutional buildings (outside Carlisle)	Operation of computer server farms (including cloud computing)
Agriculture (outside Carlisle)	Landscaping services (within Carlisle)

[27] Email exchanges between Peter Mastromarino, Member, Carlisle Agricultural Commission, and Bob Zogg between May 17 and June 6, 2019.
[28] See Attachment 7 for sources and assumptions.

Figure 2-9 suggests that our estimates of direct emissions represent only about one third of Carlisle's total (direct and embedded) emissions. Carlisle's estimated total emissions (147,000 $MTCO_2e$/yr.) are based on a calculator (developed by the University of California, Berkeley) that provides total emissions estimates by zip code for the entire U.S..[29] The Berkeley calculator provides but one estimate for total emissions, but the estimate seems in line when comparing Carlisle's direct and total emissions to Massachusetts averages—see further discussion in Section 2.4.1

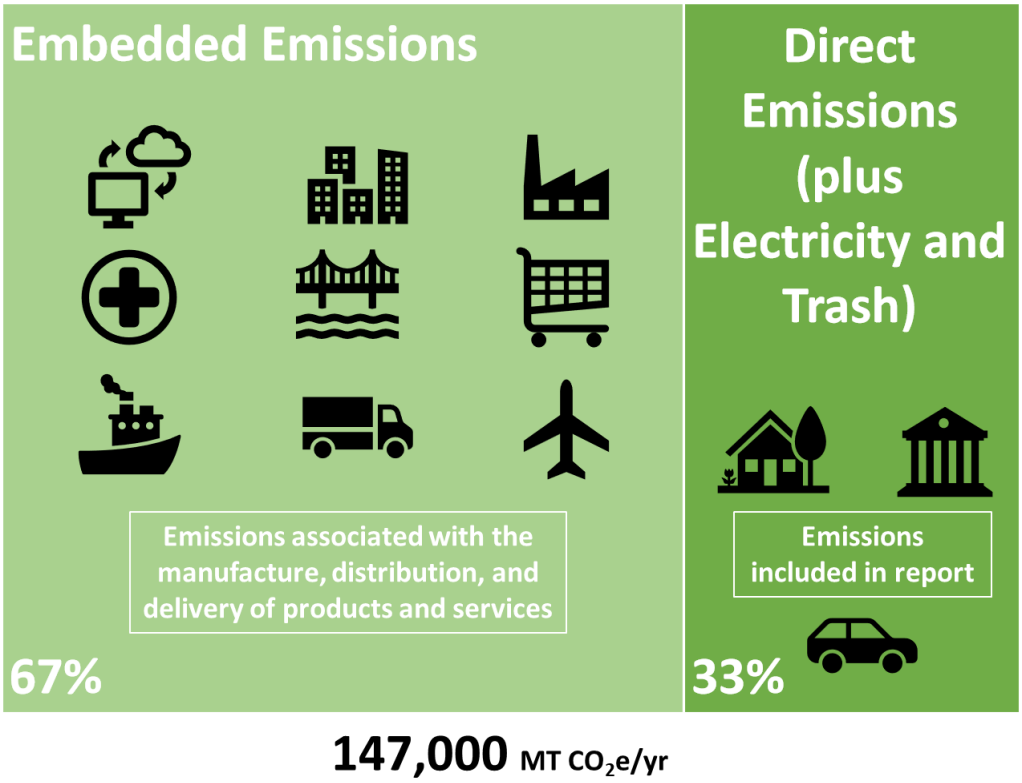


Figure 2-9: 2017 Carlisle Total (Embedded and Direct) Emissions

If we chose to, we can manage embedded emissions to some extent by managing the products and services we purchase. One example is managing the embedded emissions associated with Carlisle homes and buildings. On one hand, a new home or building is generally more energy efficient compared to an existing home/building and, hence, emits fewer emissions once it's built. However, the embedded emissions associated with a new home/building can be 50% to 70% of the life-cycle emissions of the home/building.[30]

[29] U.C. Berkeley CoolClimate Calculator; as reported by Christopher M. Jones, Director of the CoolClimate Network, in a 01-24-2019 email to Debbie Bentley. We converted the calculator's per-household estimate (83 $MTCO_2e$/yr./household) to the total for Carlisle based on the number of housing units in Carlisle.

[30] *Methodology to calculate embodied carbon, First Edition*; RICS Professional Guidance, Global; ISBN 978-1-78321-056-5; May 2014. Available at: https://webcache.googleusercontent.com/search?q=cache:wFoveflREwkJ:https://globalabc.org/uploads/

Many commonly used building materials are petroleum-based such as asphalt shingles, vinyl siding and poly-iso insulation. Concrete, brick, and steel manufacturing use considerable amounts of energy. We can lower embedded emissions by changing how we design and build our homes/buildings to use materials that capture and store carbon, such as cross-laminated timber (CLT), Hempcrete, and insulated foundations,[31] or materials that can be recycled at the end of use, such as metal roofing.

Given the magnitude of embedded emissions associated with new construction, we can lower emissions significantly if we factor them into re-use versus replace decisions for Carlisle's homes and buildings. In many cases, re-using an existing home/building results in lower life-cycle emissions, even when considering differences in energy efficiency.[32] Many factors can complicate the re-use/replace decision-making process. For example, Carlisle has struggled for many years without success to identify ways to re-purpose its Highland Building (seeFigure 2-10).

Figure 2-10: Carlisle's Highland Building

Carlisle's total emissions are much larger than the direct emissions that we can estimate because the vast majority of the products and services we use are from sources outside Carlisle. Any community trying to estimate its emissions faces a similar challenge.

2.2 Carlisle's Progress

This section summarizes Carlisle's past and current activities to promote renewable energy, lower energy use, and lower carbon emissions; to the extent we know them.

2.2.1 Carlisle Climate Action Committee

In 2008, Carlisle established the Carlisle Climate Action committee (originally called the Carlisle Climate Action-Environment committee). The committee produced a Carlisle Climate Action Plan (October 2010), but disbanded in 2011, and the plan was not implemented.[33] See Appendix A for the report.

media/default/0001/01/5214e617d8b555f132431aeddfc95e3907d41b2d.pdf+&cd=1&hl=en&ct=clnk&gl=us

[31] Northeast Sustainable Energy Association, BuildingEnergy Boston 2019 Keynote Session. Available at: https://nesea.org/buildingenergy-boston-2019-keynote-session

[32] The Greenest Building: Quantifying the Environmental Value of Building Reuse; by the Preservation Green Lab, National Trust for Historic Preservation; 2011. Available at: https://forum.savingplaces.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=5119e24d-ae4c-3402-7c8e-38a11a4fca12&forceDialog=0

[33] Information in Section 2.2.1 is based on emails from Randy Brown (committee member) to Bob Zogg in November and December 2018. Committee members included Launa Zimmaro, Bob Luoma, Mike Hanauer, Cindy Nock, Randy Brown, and others.

2.2.2 Massachusetts Green Communities

Carlisle has been a Massachusetts Green Communities member since 2011. The Green Communities Division of the Massachusetts Department of Energy Resources provides grants to help municipalities reduce energy use and costs by implementing clean energy projects in municipal buildings, facilities, and schools. Through the Carlisle Energy Task Force, Carlisle initiated numerous projects under Green Communities that lowered municipal greenhouse gas emissions by about 22% through Fiscal 2019 (compared to Fiscal 2009).[34] (This estimate does not include emissions reductions associated with Carlisle's Community Choice Power Supply program—see Section 2.2.6.) Through FY 2019, Green Communities allowed Carlisle to leverage about $821,000 in state funding and utility incentives[35] to save an estimated $121,000/year in energy costs, or a cumulative estimated savings of $435,000 through FY 2019.[36] To be eligible for Green Communities, Carlisle:

- Pledged to cut municipal energy use by 20% over five years
- Passed zoning in designated locations for the as-of-right siting of renewable or alternative energy generating facilities (aka, the solar overlay district)
- Adopted expedited application and permitting for siting renewable energy generating facilities
- Established an energy use baseline inventory for municipal facilities, vehicles, and street/traffic lighting
- Adopted a fuel-efficient vehicle policy
- Adopted the Massachusetts' Board of Building Regulations and Standards (BBRS) Stretch Code (780 CMR 115.AA).

2.2.3 Solarize Mass

In 2013, through the Carlisle Energy Task Force, Carlisle participated in Solarize Massachusetts (Solarize Mass), a program sponsored by the Massachusetts Clean Energy Center to increase the adoption of small-scale solar electricity (AKA, solar photovoltaics) in participating communities (see Figure 2-11). Under Solarize Mass, Carlisle installed over 380 kW of new solar capacity (54 homes) bringing Carlisle's installed solar capacity to over 540 kW.[37]

[34] "Emissions over time" tab, Mass Energy Insight (MEI) Database, Green Communities Program, Massachusetts Department of Energy Resources; accessed on 01-14-2020. Available at (password protected): https://massenergyinsight.net/reports/view/3420228

[35] These utility incentives are not associated with the Green Communities program.

[36] Carlisle Energy Task Force Update; Carlisle Board of Selectmen Meeting; May 28, 2019. Minutes available at: https://www.carlislema.gov/AgendaCenter/ViewFile/Minutes/_05282019-1786

[37] See Carlisle Mosquito Article under "Green Corner" for Nov. 21, 2013. Available at: http://carlislemosquito.org/index.php/feature/27-features/feature-articles/27310-green-corner-the-little-town-that-did

Figure 2-11: Residential Rooftop Solar Panels installed during the Solarize Mass Campaign

2.2.4 Carlisle Solar Challenge

During 2015 and 2016, the Carlisle Energy Task Force organized a second solar program without outside support. Under the Carlisle Solar Challenge, Carlisle residents installed 220 kW of solar capacity, and indirectly influenced the purchase of an estimated additional 180 kW, for an estimated addition of 400 kW of solar capacity.[38]

We estimate that, as of December 2018, Carlisle had about 1,000 kW (1 MW) of solar capacity generating about 1500 MWh/year of electricity, or about 6% of Carlisle's electricity consumption.[39]

2.2.5 HeatSmart Carlisle/Concord/Lincoln

From February through August 2018, members of the Carlisle Energy Task Force led a three-town HeatSmart initiative (Carlisle, Concord, and Lincoln), sponsored by the Massachusetts Clean Energy Center and the Massachusetts Department of Energy Resources. HeatSmart is a community-led initiative to learn about and purchase clean energy technologies. Under this program, Carlisle residents installed 11 air-source heat pumps, 7 ground-source heat pumps, and one modern wood heating system. (Installations in the three towns totaled 49, 23, and one, respectively.)[40] We anticipate significant additional installations resulted, and continue to result, from awareness generated through this program. Since the end of the HeatSmart program, the towns continue to collaborate to promote heat-pump installations. The HeatSmart Alliance, as this group is now known, has grown to include 17 towns.[41]

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[38] Per 08/27/2017 email communication from Claude von Roesgen (Coach for Carlisle Solar Challenge) to Bob Zogg

[39] Assuming about 1,500 kWh/year per kW installed capacity. In 2017, Carlisle consumed about 25,000 MWh of electricity (based on data from Eversource).

[40] Based on numbers of installer contracts signed. Numbers of contracts signed are as reported by HeatSmart installers to The Cadmus Group, and then reported to Bob Zogg, Carlisle HeatSmart Coach, by email on 09/09/2018.

[41] As of 03/30/2020, the HeatSmart Alliance consists of Acton, Arlington, Ashland, Belmont, Boxborough, Carlisle, Concord, Hudson, Lincoln, Maynard, Medfield, Natick, Newton, Stow, Sudbury, Wayland, and Winchester. See: http://heatsmartalliance.org/

2.2.6 Transition to Community Choice Power Supply

With support from the Carlisle Energy Task Force, effective, July 1, 2018, the Town of Carlisle entered a 30-month contract with Colonial Power Group (broker) to receive electricity through a Community Choice Power Supply program (aka, Municipal Aggregation).[42] The default offering under the program is 100% renewable electricity secured through the purchase of National Wind Renewable Energy Certificates (RECs).[43] As of July 1, 2018, any Carlisle electricity customer who was previously purchasing their electricity from Eversource was switched to 100% renewable electricity, unless that customer opted out—see Figure 2-12.[44] Between October 2018 and June 2019, an average of 1,476 residential customers and 73 commercial customers received their electricity through this 100% renewable program option. Only 22 customers elected to take the lower-cost program option, which just meets Massachusetts requirements for renewable energy content and saves $0.00102/kWh (about 0.5%).[45] Therefore, at least 80% of Carlisle's 1,773 occupied housing units are supplied with 100% renewable electricity supply through the purchase of RECs.[46, 47]

Figure 2-12: Congratulatory Poster for Carlisle's Transition to Renewable Energy

2.2.7 Municipal Waste Disposal

In late 2018/early 2019, the Carlisle Household Recycling Committee (CHRC), with the assistance of other community volunteers, developed a plan and a proposed warrant article (intended for Carlisle's 2019 Town Meeting) to switch Carlisle to a Pay As You Throw (PAYT) system for non-recyclable waste disposal. Because of mixed reviews from the community, the CHRC decided to withdraw the proposed warrant article for the 2019 Town Meeting. Instead, the CHRC recommended to the Carlisle Board of Selectmen several actions:

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[42] See description and rate information at Colonial Power's website: https://colonialpowergroup.com/carlisle/

[43] In 2018, about 77% of the RECs were National Wind RECs, with the remainder from sources mandated by the MA Renewable Energy Portfolio Standard (RPS). See explanation of the RPS at: https://www.mass.gov/renewable-energy-portfolio-standard

[44] Eversource remains the distribution company for Carlisle, and Carlisle customers continue to receive their electric bills from Eversource.

[45] *Town of Carlisle Community Choice Power Supply Program—Status Report Q1 2019*; prepared by Colonial Power Group; June 2019. Available at: https://www.carlislema.gov/DocumentCenter/View/1967/Carlisle-Aggregation-Quarter-Report---June-2019

[46] Number of Carlisle housing units for 2017 from 2017 American Community Survey, Selected Housing Characteristics; American FactFinder; U.S. Census Bureau. Available at: https://factfinder.census.gov/bkmk/table/1.0/en/ACS/17_5YR/DP04/0600000US2501711525

[47] The housing units not accounted for presumably have independent contracts for their electricity supplies, rather than receiving electricity through Community Choice. Some of these housing units may purchase renewable electricity through their independent contracts.

- Top Priority:
    - Discontinue the collection of construction and demolition debris (individual households would need to arrange disposal of such items)
    - Initiate a municipal composting program
- Additional Actions to Consider:
    - Implement fees for bulky items
    - Increase transfer-station sticker fees
    - Monitor sticker compliance.[48]

2.2.8 Municipal Solar

Based on analyses conducted by the Carlisle Energy Task Force, the Carlisle Board of Selectmen directed Carlisle's Town Administrator to appoint a Solar Working Group. The Solar Working Group gained approval of a series of warrant articles at Carlisle's 2019 Town Meeting authorizing the installation of solar-electric canopies at the transfer station and the Carlisle Public School (see Figure 2-13).[49] Subsequently, concerns about a potentially uncapped landfill under the transfer station led the Solar Working Group to reduce the scope to include a canopy at the school only. A third-party owner/operator is designing and installing the canopy, and will own and operate the canopy at no cost to the Town. In fact, the installation is expected to generate $676,000 in lease payments for the Town over the next 20 years. The Solar Working Group is leveraging the Solar Massachusetts Renewable Target (SMART) program to make this installation possible.[50]

Figure 2-13: Solar Canopies at Carlisle Public School (Summer 2020 Projected Completion)

[48] Letter to the Carlisle Board of Selectmen; Re: Carlisle Household Recycling Committee—Town Meeting Warrant Article; from the Carlisle Household Recycling Committee; March 22, 2019.
[49] Lyons, Helen; *Articles 24-26 – Solar project approved*; Page 1, Carlisle Mosquito, Volume 36, May 3, 2019. Available at: http://www.carlislemosquito.org/index.php/archive-pulldown/archived-editions/49-pdf-edition/34867-pdf-edition-may-10-2022
[50] More information about the SMART program is available at the Massachusetts Department of Energy Resources website: https://www.mass.gov/solar-massachusetts-renewable-target-smart

2.2.9 Community Composting

The Carlisle Household Recycling Committee, working with the Carlisle Department of Public Works, organized a community composting program. As of June 4, 2019, Carlisle residents can deposit food scraps and other compostable organic materials in designated bins at the transfer station. Food scraps make up about 30% of solid waste that is sent to incinerators or landfills.[51] Reducing Carlisle's solid waste reduces the Town's incineration fees, GHG emissions associated with waste incineration, and landfill requirements for incinerator ash.

2.2.10 New Carlisle Master Plan

Carlisle's Master Plan Steering Committee began meeting in 2018 to prepare a new master plan for Carlisle. At the 2019 Carlisle Town Meeting, residents approved Warrant Article 12, which authorized funding to hire a consulting firm to assist with developing the Master Plan.[52] The Steering Committee has identified environmental sustainability as a key component of the new plan. The Steering Committee selected a consulting firm in August 2019 and launched the official process in September 2019. Carlisle expects to complete the new master plan by September 2020.

2.3 Carlisle's Energy Consumption and Emissions Trends

We examine below trends over time associated with residential energy consumption and greenhouse-gas emissions, as well as the overall emissions impacts of Carlisle's Community Choice Power Supply program.

2.3.1 Trends in Residential Energy Consumption

Figure 2-14 shows that Carlisle's population has grown by 20% from 1990 to 2017. Figure 2-15 shows that, during the same time period, Carlisle's ***residential energy consumption*** increased by 18% (see Figure 2-15), indicating little change in ***per-capita residential energy consumption*** over 27 years, despite:

- Increased insulation and air-sealing requirements in building codes
- Improved motor-vehicle fuel economies

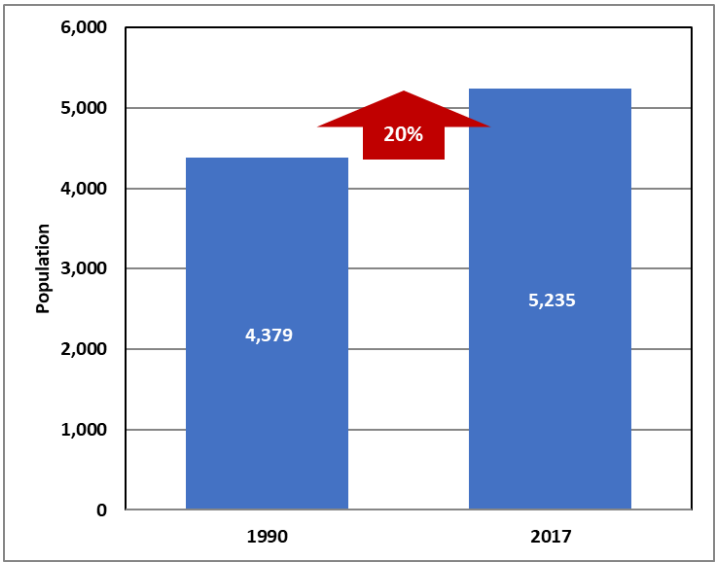


Figure 2-14: Carlisle Population Trend--1990 to 2017[53]

[51] Household Recycling Committee; *Transfer Station composting starts June 4*; May 29, 2019; Carlisle Mosquito. Available at: http://www.carlislemosquito.org/index.php/archive-pulldown/archived-articles/18-news/news-articles/34943-transfer-station-composting-starts-june-4

[52] See: https://www.carlisleplan.org/ and https://www.carlislema.gov/779/Master-Plan-Steering-Committee

[53] See Attachment 1 for sources

- Improved efficiencies of residential lighting, appliances, and heating/cooling equipment
- Growing awareness of the climate impacts associated with energy consumption.

Increasing home size has likely offset, at least in part, these factors. The average new house built in Carlisle between 2000 and 2016 was about 5,050 square feet, compared to an average existing house size in 1990 of about 3,180 square feet.[54]

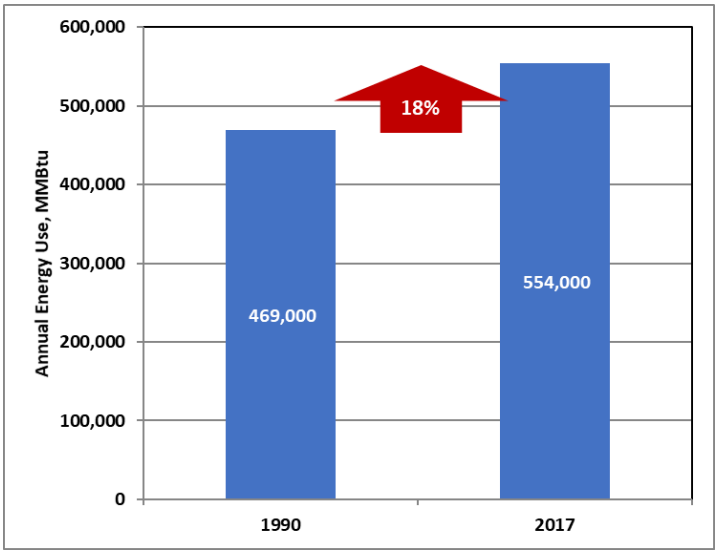


Figure 2-15: Carlisle Residential *Energy Consumption* Trends--1990 to 2017[55]

2.3.2 Trends in Residential Greenhouse-Gas Emissions

Over the same period (1990 to 2017), Carlisle's ***residential greenhouse-gas emissions*** were virtually unchanged (see Figure 2-16) because the ***emissions*** associated with electricity generation in New England dropped significantly during this time period, translating to 57% lower ***emissions*** per unit of electricity consumed.[56]

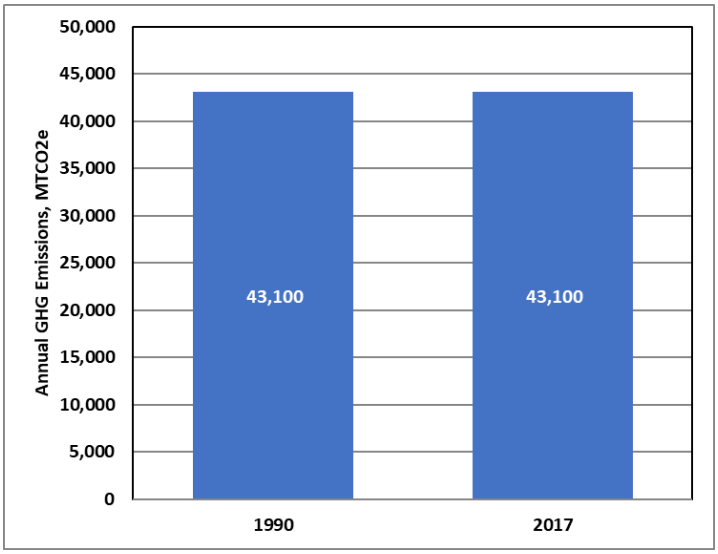


Figure 2-16: Carlisle Residential *Emissions* Trends--1990 to 2017[57]

2.3.3 Impacts of Community Choice Power Supply Program

In July 2018, Carlisle's emissions dropped sharply when Carlisle switched to its Community Choice Power Supply program (see Section 2.2.6 above). We estimate that this step alone reduced Carlisle's emissions by about 6,900 $MTCO_2e$/year, providing about a ***77% reduction in***

[54] Estimated based on Carlisle's 2015 tax-assessment database.
[55] See Attachment 1 for sources and assumptions. Units are millions of British thermal units per year. Does not include energy lost in the generation, transmission, and distribution of electricity.
[56] Estimated electricity emissions factors were 0.00081 $MTCO_2e$/kWh in 1990 and 0.00035 $MTCO_2e$/kWh in 2016. See Attachment 1 for further details.
[57] See Attachment 1 for sources and assumptions

Carlisle's electricity emissions and about a 14% reduction in Carlisle's overall emissions (see Figure 2-17).[58]

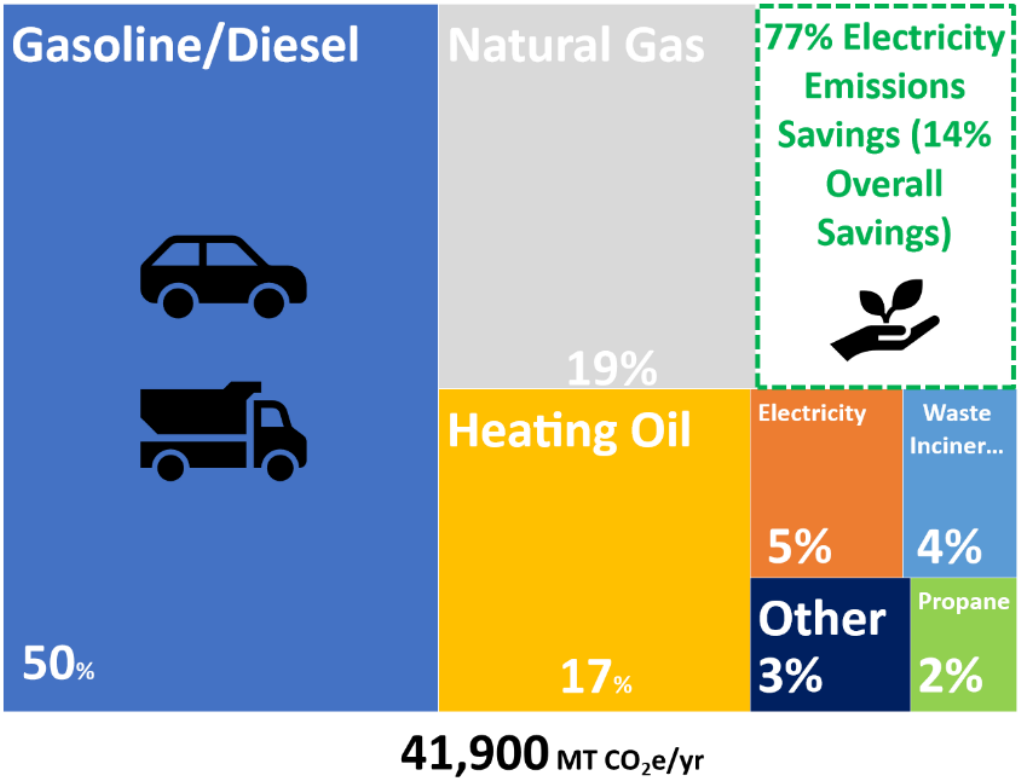


Figure 2-17: Carlisle Direct Emissions after switch to Community Choice Power Supply (July 2018)

As noted in Section 2.2.6 above, this improvement came at the modest cost premium of about $0.00102/kWh (but was still cheaper than Eversource through the end of Calendar 2019), or less than $12 annually for the average Carlisle household (using about 11,400 kWh/year).[59] This cost premium is in effect through the end of Calendar 2020. Future cost premiums for renewable electricity may be different. Also, see the discussion in Appendix B about challenges and uncertainties associated with renewable electricity.

2.4 Emissions Comparisons

Below we compare emissions estimates for Carlisle to Massachusetts averages, to Concord, MA, and to U.S. averages.

2.4.1 Comparisons to Massachusetts Averages

For Massachusetts, we compare both direct and total (direct and embedded) emissions below.

[58] See Attachment 2 for sources and assumptions
[59] Based on 2017 electricity consumption data from Eversource, provided by Colonial Power Group in January 2018

2.4.1.1 Direct Emissions

2017 per-capita residential-building emissions (excluding vehicles) were:

- ***In Massachusetts:*** 3.12 $MTCO_2e$/person/year
- ***In Carlisle:*** 4.41 $MTCO_2e$/person/year.[60]

Therefore, Carlisle's per-capita residential-building emissions are about 41% higher than the Massachusetts average.

2.4.1.2 Total (Direct and Embedded) Emissions

Based on a calculator developed by the University of California, Berkeley, Carlisle's per-capita total (direct and embedded) emissions are, on average, 43% higher than for Massachusetts (see Figure 2-18). [61]

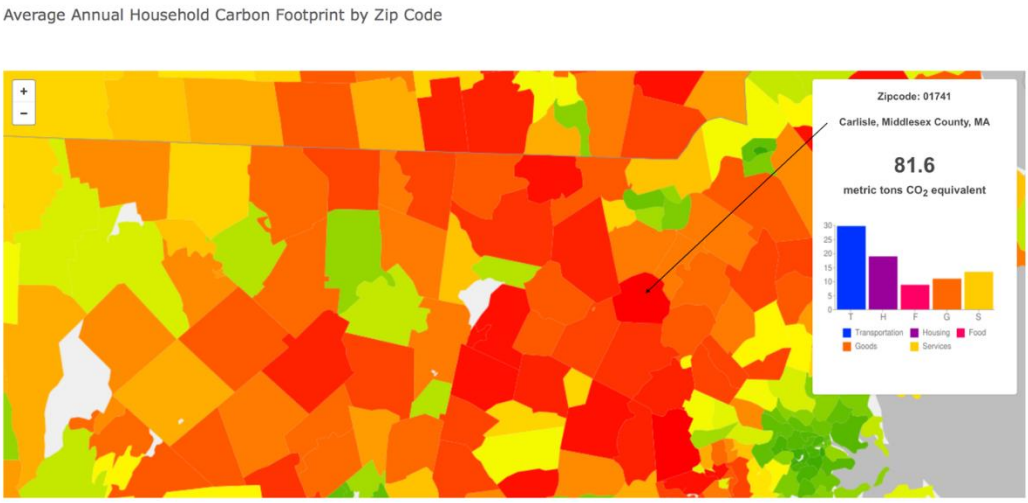


Figure 2-18: 2013 Average Annual Household Carbon Footprint (Direct and Embedded) for Carlisle[62]

Carlisle, MA is residential community consisting of mostly single-family homes, with very few businesses. Zoning ordinances require each residential lot to be at least two acres in most parts of Carlisle, giving the community a semi-rural feel despite its proximity to Boston. Carlisle's average household income is higher than average in Massachusetts and the average home size reflects this. Perhaps because we are further from urban hubs than many other communities, we drive more, too. Compared to the average Massachusetts resident, the average Carlisle resident:

[60] See details in Attachment 1.
[61] U.C. Berkeley CoolClimate Calculator; as reported by Christopher M. Jones, Director of the CoolClimate Network, in a 01-24-2019 email to Debbie Bentley. Expressed per capita.
[62] From U.C. Berkeley CoolClimate Calculator: https://coolclimate.berkeley.edu/maps

- Has a home that provides 45% more floor space *per occupant*[63, 64, 65]
- Drives 40% more miles (19.0 vs. 26.5 miles/day/person)[66]
- Has an annual income that is 115% higher.[67]

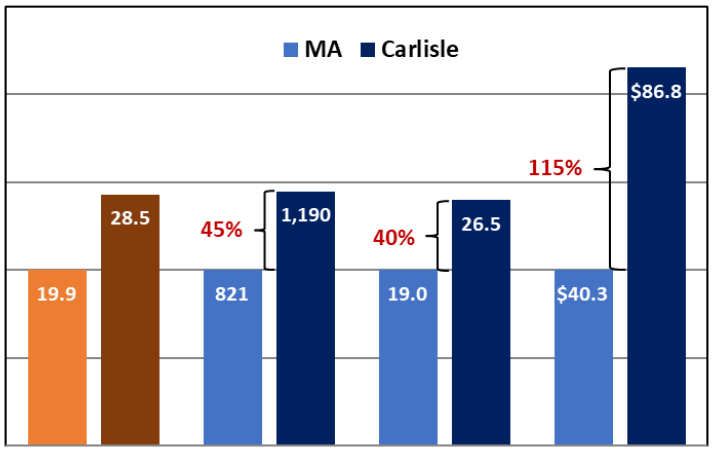


Figure 2-19 compares these per-capita metrics for Carlisle and Massachusetts. It seems likely that differences in home size, vehicle use, and income are primary contributors to differences in emissions. While the figure includes emissions in addition to those examined in this report, the trend is consistent with the results for direct emissions from residential buildings, reported in Section 2.4.1.1 above.

a) Average household vehicle use divided by average occupants per household (including non-drivers).

Figure 2-19: Comparison of Various Per-Capita Metrics—Massachusetts vs. Carlisle[68]

[63] Carlisle average home size estimated from Carlisle's 2015 tax-assessment database at 3,500 sq. ft.
[64] Massachusetts average home size (2076 sq. ft.) is for 2009. From the U.S. Department of Energy, Energy Information Administration; 2009 Residential Energy Consumption Survey; Household Energy Use in Massachusetts. Available at: https://www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/ma.pdf
[65] 2017 average occupants per household are 2.54 for MA and 2.91 for Carlisle. From Selected Housing Characteristics, American FactFinder, U.S. Census Bureau. Available at: https://factfinder.census.gov/bkmk/table/1.0/en/ACS/17_5YR/DP04/0100000US
[66] Based on 2014 values of 48.0 miles/household for MA and 77.2 miles/household for Carlisle, expressed per capita. From the Metropolitan Area Planning Council; Massachusetts Vehicle Census, Municipal Summary. Available at: https://www.mapc.org/learn/data/
[67] Based on 2017 values of $101,858 per household for MA and $252,373 per household for Carlisle, expressed per capita. From U.S. Census Bureau, American Fact Finder, 2017 American Community Survey, Selected Economic Characteristics. Available at:
MA: https://factfinder.census.gov/bkmk/table/1.0/en/ACS/17_5YR/DP03/0400000US25
Carlisle: https://factfinder.census.gov/bkmk/table/1.0/en/ACS/17_5YR/DP03/0600000US2501711525
[68] Floor space data are for 2015, vehicle use data are for 2014, income data are for 2017. See Attachment 1 for further details.

2.4.2 Comparisons to Concord, MA

The Town of Concord, MA retained a professional consulting firm to estimate its greenhouse gas emissions for 2008 and 2016.[69, 70] Comparing estimated residential-building emissions (excluding vehicles) for Concord and Carlisle:

- 2016 per-capita emissions for Concord: 4.67 $MTCO_2e$/person/year
- 2017 per-capita emissions for Carlisle: 4.41 $MTCO_2e$/person/year.[71]

This comparison would suggest that Carlisle's per-capita residential-building emissions are about 6% lower compared to Concord. The Concord Municipal Light Plant procures electricity from different sources than does Eversource (Carlisle's electricity supplier in 2017), which could impact emissions comparisons. However, when comparing per-capita *energy consumptions* (rather than emissions), the differences between the two towns were even greater—Carlisle's residential-building *energy consumption* is about 15% less. We suspect that these differences reflect differences in methodologies, rather than actual differences in residential-building energy consumptions or emissions.[72]

We were not able to make meaningful comparisons for other sectors because a) Concord has a much larger commercial base compared to Carlisle, b) the Concord report does not breakout transportation emissions separately for commercial and residential, and c) the Concord report does not breakout municipal and agricultural emissions.

2.4.3 Comparisons to U.S. Averages

Figure 2-20 compares per-capita total emissions estimates for the U.S., Massachusetts, and Carlisle. As the figure shows, Massachusetts per-capita emissions are almost the same as for the U.S. Carlisle's per-capita total emissions are about 44% higher than for the U.S.

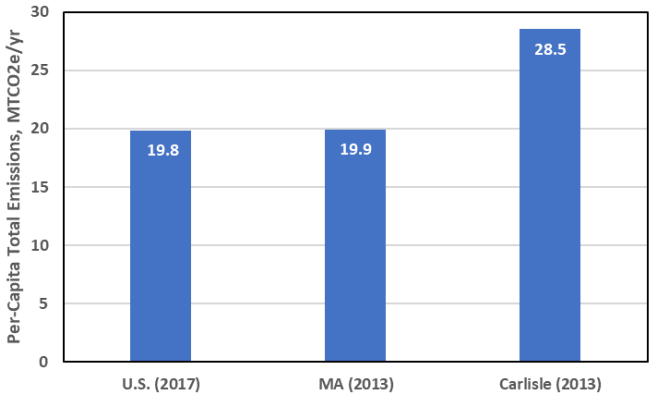


Figure 2-20: Comparisons of Per-Capita Total Emissions

[69] *Town of Concord Community Greenhouse Gas Emissions Inventory 2008 and 2016*; Kim Lundgren Associates, Inc.; January 2019. Available at: https://concordma.gov/DocumentCenter/View/19103/Concord-Community-GHG-Inventory-Full-Report--Methodology

[70] The cost for this report was about $37,000. Per email from Kate Hanley, Concord Sustainability Director, to Bob Zogg; July 1, 2019.

[71] See details in Attachment 8.

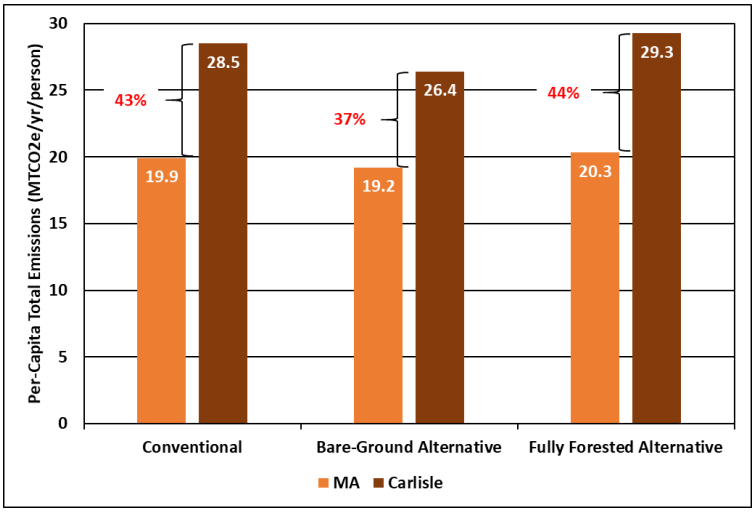
[72] We are unable to resolve a difference in estimated emissions associated with natural-gas leakage. The Concord report shows only a 1.5% increase in natural-gas emissions associated with leakage, while our calculations indicate a 25% to 28% increase using the same estimated leakage rate. This may explain why the difference in per-capita emissions is less than the difference in per-capita energy use. See comparison in Attachment 8.

2.5 Carbon Sequestration by Carlisle's Forests and Woodlands

Consistent with conventional practice, the emissions estimates presented above do not account for the carbon sequestration of Carlisle's forests and woodlands (see Figure 2-21). Forest/woodlands carbon sequestration refers to the ability of forests and woodlands to extract carbon dioxide from the atmosphere and convert it to stored carbon in the trunks, limbs, leaves, and roots of trees. Carbon s*equestration* is not the same as carbon *storage*.

Figure 2-21: Carlisle Woodlands

Sequestration is expressed as a rate of carbon dioxide extraction (removal over time), while *storage* refers to the total amount stored at any point in time.



How would Carlisle's emissions look if we accounted for forest/woodlands sequestration? The answer depends on the alternative to which we wish to compare. Figure 2-22 compares per-capita total emissions for Massachusetts and Carlisle as estimated in this report (i.e., following conventional practice) to two alternatives:

Figure 2-22: Impacts of Forest/Woodlands Sequestration for Massachusetts and Carlisle[73]

- ***Conventional Practice:*** Does not account for forest/woodlands sequestration
- ***Bare-Ground Alternative:*** Includes sequestration impacts for today's forest cover relative to the impacts of having no natural ground cover
- ***Fully Forested Alternative:*** Includes sequestration impacts for today's forest cover relative to the impacts of a fully forested landscape.

The rationale for including the Fully Forested Alternative is that, prior to development, Massachusetts (including Carlisle) was predominantly forested, and overall carbon emissions and sequestration were generally in balance, with an atmospheric carbon dioxide concentration

[73] Estimates of carbon sequestration by northeastern forests vary significantly. See details in Attachment 9.

of about 280 parts per million during interglacial periods.[74] One could argue that, instead of taking credit for the sequestration by the forests/woodlands we have preserved, we should instead account for the lost sequestration associated with the forests/woodlands we have removed.

The impacts of accounting for forest/woodlands sequestration:

- Lower Carlisle total emissions by about 7% compared to a bare-ground alternative
- Increase Carlisle total emissions by about 3% compared to a fully forested alternative.

When comparing Carlisle's emissions to the Massachusetts average, accounting for forest/woodland sequestration has only modest impacts.

3 Options for Emissions Goals

We outline options below for Carlisle emissions goals and a sustainability mandate.

3.1 Sustainability Mandate for Carlisle

The Carlisle Energy Task Force endorsed a proposed sustainability Mandate for Carlisle (see Table 3-1). Carlisle may wish to adopt the proposed sustainability mandate or one similar to it.[75]

Table 3-1: Proposed Sustainability Mandate for Carlisle

Proposed Sustainability Mandate for Carlisle [a]
The Town of Carlisle seeks to become a sustainable community and attain environmental and economic benefits by planning for a more livable community, through applying smart growth and zoning policies, reducing community-wide energy and water consumption [b], securing more environmentally friendly energy sources, adopting sustainable procedures in municipal management, purchasing, and maintenance procedures, education and encouraging the residents to adopt a sustainable lifestyle, and supporting the important role of the natural environment and our heritage that is necessary for our future generations, including resilience planning and implications for the issues the town will face In the future.

a) Endorsed by the Carlisle Energy Task Force at its August 8, 2016 meeting.
b) "Community-wide energy and water consumption" includes residential, municipal, commercial, agricultural consumptions for both transportation and the built environment. Water consumption is not examined in this report.

3.2 Candidate Emissions Goals for Carlisle

We outline various options for emissions goals below, after providing some background and context.

[74] Historic carbon dioxide concentration from the NASA Global Climate Change website: https://climate.nasa.gov/climate_resources/24/graphic-the-relentless-rise-of-carbon-dioxide/

[75] Carlisle may wish to change "… adopting sustainable procedures *in* municipal management, purchasing, and *maintenance procedures.*" to "… adopting sustainable procedures *for* municipal management, purchasing, and *maintenance.*"

3.2.1 Massachusetts Global Warming Solutions Act

The MA Global Warming Solutions Act of 2008 (GWSA) set goals for reductions in Massachusetts economy-wide greenhouse gas emissions, relative to 1990 statewide emissions levels, of:

- 25% by 2020
- 80% by 2050.[76]

3.2.2 Intergovernmental Panel on Climate Change

A 2018 special report from the Intergovernmental Panel on Climate Change (IPCC) indicates that climate change is happening faster than previously predicted, giving scientists "high confidence" that "[l]imiting warming to 1.5°C implies reaching net zero CO_2 emissions globally around 2050 and concurrent deep reductions in emissions of non-CO_2 forcers, particularly methane."[77] The authors also express "high confidence" that "[l]imiting warming to 1.5°C depends on greenhouse gas (GHG) emissions over the next decades, where lower GHG emissions in 2030 lead to a higher chance of keeping peak warming to 1.5°C." The authors imply that GHG emissions reductions of 40% to 60% by 2030 (from 2010 levels) are needed to limit warming to 1.5°C, in addition to reaching net zero emissions by around 2050.[78]

3.2.3 Why should Carlisle consider adopting Goals?

One could argue that setting emissions goals at the community level is redundant, given that the state has already set goals. However, state goals alone may be insufficient. While the state has demonstrated that it can require New England's electric power generators to lower emissions, will it be effective at tackling emissions associated with individuals, small businesses, and municipal operations?[79] Further, do we envision the state somehow lowering emissions from communities without their active involvement and engagement? Or, is it more likely that the state is relying on communities to take local action to support state goals? Further, current state goals are not adequate to meet the recommendations for emissions reductions from the Intergovernmental Panel on Climate Change (see Section 3.2.2 above).

3.2.4 What are other Communities Doing?

Table 3-2 summarizes community-wide emissions-related goals for some other eastern Massachusetts communities. Based on this sample, a number of regional communities have adopted quantitative goals, and those goals tend to align with the MA Global Warming Solutions

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[76] Massachusetts Executive Office of Energy and Environmental Affairs. See: https://www.mass.gov/progress-towards-reducing-greenhouse-gas-emissions
The Conservation Law Foundation, a New England environmental advocacy organization, interprets GWSA goals to be mandates. See: https://www.clf.org/making-an-impact/global-warming-solutions-act/

[77] Page 33, Technical Summary; *Global Warming of 1.5°C*; Intergovernmental Panel on Climate Change; IPCC SR1.5; October 8, 2018. Available at: http://www.ipcc.ch/report/sr15/

[78] Ibid.

[79] Richmond, Steve, et. al.; *Massachusetts Supreme Judicial Court Upholds GHG Caps for Electricity Sector and Affirms the Continued Viability of Chevron-style Deference in Massachusetts*; Beveridge & Diamond; September 11, 2018. Available at: https://www.bdlaw.com/publications/massachusetts-supreme-judicial-court-upholds-ghg-caps-for-electricity-sector-and-affirms-the-continued-viability-of-chevron-style-deference-in-massachusetts/

Act of 2008 (GWSA). Some towns exclude transportation from their goals, focusing instead on home/building energy and emissions.

Table 3-2: Summary of Emissions Goals for Selected Massachusetts Communities

Community	Emissions Goals Summary [a]	Comments
Acton	Reduce emissions of carbon dioxide and other greenhouse gases	Qualitative goals
Bedford	Aligned with GWSA	Baseline year is to be established
Boxborough	20% reduction in building energy use and other qualitative goals	Mostly qualitative goals, except for building energy use
Cambridge	70% reduction by 2040 for the built environment (excludes transportation) Net zero / carbon-free status in the region by 2050	2040 goal is roughly consistent with the GWSA, given that transportation is not included
Concord	Aligned with GWSA, except using a 2008 baseline	Added a goal to have 100% non-carbon-emitting electricity by 2030 (not in the GWSA)
Harvard	None identified	
Lexington	25-year goal to reduce emissions and transition to renewable energy	Qualitative goal
Lincoln	None identified	
Sherborn	None identified	
Somerville	By 2050, become carbon-neutral and use 100% renewable energy	Established community climate change plan
Winchester	By 2050, reach at least 80% reduction below 2006 baseline	Unanimous vote by Select Board on 04/22/2019

a) See further details in Appendix C.

3.2.5 Options for Emissions-Reduction Goals

Based on the discussion above, two logical options emerge should Carlisle choose to adopt emissions goals (see Table 3-3). While the second option (align with the 2018 report by the Intergovernmental Panel on Climate Change) is the more ambitious of the two options, it's consistent with more recent projections by climate scientists to limit global temperature rise to 1.5°C. This goal is consistent with a 10% average annual emissions reduction from 2020 through 2050. Further, in his January 21, 2020 State of the Commonwealth address, Governor Baker pledged Massachusetts to a new goal of net-zero carbon emissions by 2020.[80] This pledge may render the current GWSA goals obsolete.

[80] Transcript available at: https://www.mass.gov/news/governor-baker-delivers-2020-state-of-the-commonwealth-address

Table 3-3: Options for Carlisle Emissions-Reduction Goals

Option 1	Option 2
Align with MA Global Warming Solutions Act of 2008 [a] • By 2030, 40% Town-wide emissions reduction (compared to a 2017 baseline) [b] • By 2050, 80% Town-wide reduction • 5% average annual reduction	***Align with Intergovernmental Panel on Climate Change (2018 Report)*** • By 2030, 65% Town-wide emissions reduction (compared to a 2017 baseline) [b] • By 2050, 95% Town-wide reduction [c] • 10% average annual reduction

a) On January 21, 2020, Governor Baker pledged MA to a new goal of net-zero emissions by 2050
b) 2030 goals based on a fixed annual percentage emissions reduction from 2020 through 2050. "Town-wide emissions" include residential, municipal (including waste disposal), commercial/institutional, and agricultural emissions.
c) The IPCC report suggests reaching net-zero global emissions by 2050 to limit warming to 1.5°C. We suggest a slightly less ambitious goal (95% reduction) to reflect the likelihood that Carlisle will continue to use some fossil fuel in 2050.

4 Recommended Conceptual Approach to Achieve Emissions Goals

Outlined below is a conceptual approach to achieve emissions goals, should Carlisle elect to adopt such goals. We include it to provide a sense of the type of initiatives Carlisle would need to pursue to achieve these goals. This conceptual approach may change during the subsequent development of an implementation plan.

As Figure 4-1 illustrates, we recommend pursuing emissions goals by weatherizing our homes and buildings (primarily through air sealing and insulation), and switching from fossil fuels to renewably sourced electricity, combined with behavioral changes and other approaches where practical. We discuss each of these approaches below.

Key Approaches:
- **Weatherize**
- **Electrify**
- **Shift to renewable electricity**

Other Approaches:
- Behavioral changes
- Biomass heating systems
- Reforestation and forest preservation
- Improved agricultural practices

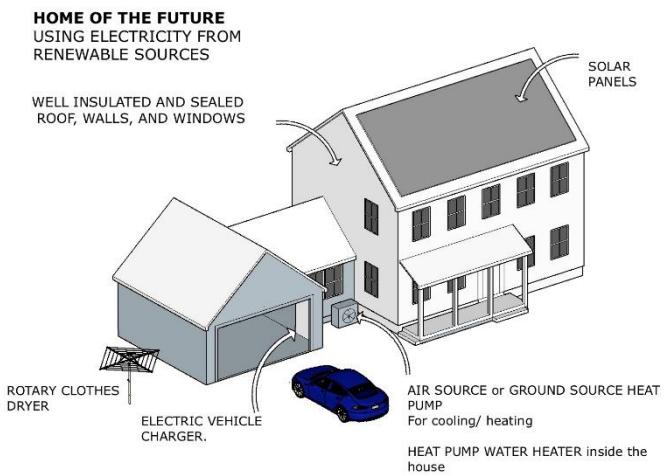

Figure 4-1: Overall Approach to Achieving Goals

4.1 Improve Energy Efficiency

Improving energy efficiency, including weatherizing homes and buildings, is the most important approach to lowering greenhouse gas emissions—see further discussion in Section 4.6. Improving energy efficiency means reducing the amount of energy required to provide energy services (such as heating, cooling, lighting, transportation, etc.), without appreciably compromising utility, convenience, or comfort to achieve the reductions. There are two general ways to improve energy efficiency:

1. Using equipment that is more energy-efficient, such as purchasing motor vehicles having more fuel-efficient engines, or installing more efficient appliances in homes and buildings
2. Lowering energy loads, such as purchasing lighter and more aerodynamic motor vehicles, or improving insulation and air sealing in homes and buildings (i.e., weatherization).

Technologies available today can significantly lower the energy used by our homes, buildings, and vehicles, such as:

- *Home/Building Examples:* Heat pumps for home heating and cooling (see Figure 4-2), heat-pump water heaters, point-of-use water heaters, heat-pump clothes dryers, LED lighting, high-efficiency motors, on-demand ventilation systems, improved insulation and sealing, and thermal-break windows
- *Vehicle Examples:* Electric vehicles and plug-in hybrid electric vehicles.

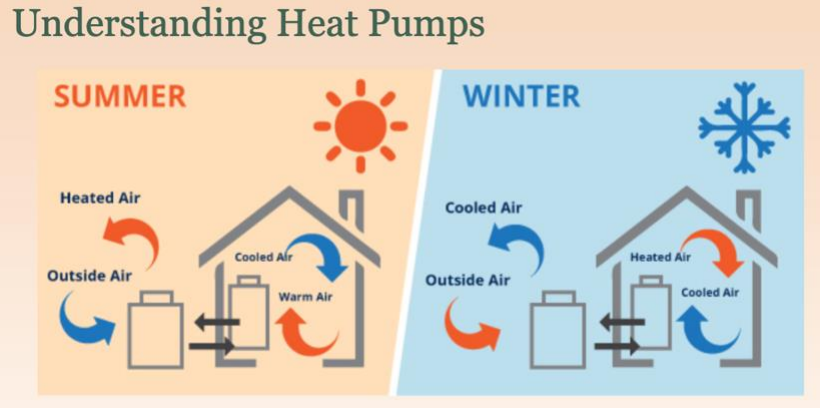

Figure 4-2: How a Heat Pump Works

Order matters when addressing the energy efficiency of our homes and buildings. Before electrifying heating and cooling equipment, one should weatherize the home or building to the extent practical. This may include:

- Air sealing and improving insulation of the home/building envelope
- Replacing components of the envelope, such as windows and doors
- Sealing and insulating air-distribution ductwork.

4.2 Electrify and Switch to Renewable Electricity

Achieving an 80% to 95% reduction in carbon emissions without changing our mix of fuel choices would require an 80% to 95% reduction in energy use—this would be a daunting task. As Table 4-1 shows, one can achieve modest emissions reductions by switching from one fossil fuel to another (for example, natural gas emits about 8% less carbon compared to fuel oil, accounting for the impacts of natural-gas leakage),[81] however, emissions can be reduced to near zero by switching to electricity generated from emissions-free sources such as renewables (wind, solar, and hydropower) or nuclear power. Therefore, most communities that are trying to reach 80% or more emissions reductions seek to switch key loads from fossil fuels to electricity from emissions-free sources. Communities that have set emissions goals are pursuing emissions reductions through a combination of lowering energy use and switching to electricity from emissions-free sources. Most of these communities consider only renewable electricity sources because of concerns about safety, security, and the environmental impacts associated with nuclear-waste storage, transport, and disposal.

Table 4-1: Greenhouse Gas Emissions Associated with Common Energy Sources[82]

Energy Source	Greenhouse-Gas Emissions ($MTCO_2e/MMBtu$) [a]	Emissions Relative to New England Grid Electricity (%)
Electricity—New England Grid	0.103 [b]	100%
Electricity—Renewable	0	0%
Electricity--Nuclear	0	0%
Natural Gas—Neglecting Leakage	0.053	52%
Natural Gas—Including Leakage [c]	0.068	66%
Fuel Oil	0.074	72%
Propane	0.062	61%
Gasoline	0.074	72%
Diesel Fuel	0.074	72%

a) Units are metric tons of CO_2 equivalent per million British thermal units (million Btu) of energy content

b) Equivalent to 0.00035 $MTCO_2e/kWh$ or 0.77 lb. CO_2e/kWh. Includes 8% losses in the electric transmission and distribution system.

c) Based on leakage rate of 2.7% for the greater Boston area.

In 2018, Carlisle took an important action to lower Carlisle's carbon emissions. As discussed in Section 2.2.6 above, on July 1, 2018, Carlisle launched its Community Choice Power Supply Program (a municipal aggregation program). Under this program, over 80% of Carlisle residents are already using electricity that is 100% renewable based on the purchase of national wind renewable energy certificates.

[81] This comparison includes the greenhouse gas emissions associated with natural-gas leakage from the natural-gas transmission and distribution network. See Section 6.2 for further explanation. Without including leakage impacts, natural gas emissions are about 28% lower than fuel oil.

[82] See Attachment 1 for sources

As explained in Appendix B, using renewable electricity may become more complex and expensive as the demand for renewable electricity increases. Therefore, the success of electrification using renewable sources may depend on how effectively cost/complexity issues are mitigated through technology advances, changes in electricity consumption patterns driven by pricing changes and education, and/or policy changes (such as carbon taxes or fees).

4.3 Change Behavior

Behavioral changes may (but don't necessarily) require giving up some utility, convenience, or comfort. Examples include:

- Carpooling, public transit, biking/walking, or simply foregoing some vehicular trips (such as working from home when possible)—see Figure 4-3
- Lowering home/building thermostat set points in winter, or raising them in summer
- Switching off lights that are not in use, or using lower levels of illumination
- During winter, opening window curtains/blinds on sunny days and closing them at night
- During summer, closing window blinds during daylight hours
- Moving to a smaller single-family home, or a multi-family home, that requires less heating and cooling
- Reducing air travel
- Consuming fewer meat and dairy products by preferring plant-based proteins (see discussion about livestock in Section 4.5)
- Recycling/reusing more, consuming less, and throwing less in the trash

Behavioral changes are effective and often inexpensive to implement. While they should not be overlooked as a piece of the solution, their impacts are limited by the extent to which individuals are willing to make changes and/or give up some utility, convenience, or comfort. Some individuals have taken behavioral change a long way, but most have not.

Figure 4-3: CrossTown Connect Bus

Getting the most from behavioral change will require lowering barriers and promoting awareness, including:

- Improving community infrastructure, such as:
  - Public transit
  - Walkways
  - Bikeways/bike lanes
- Financial incentives, such as:
  - Bill credits to permit reset of thermostats by the electric utility

    - Subsidies for commuting via public transit or carpools
- Technology improvements, such as:
    - Remote thermostat control/setback
    - Automated window blinds (in this case, changing an energy-conservation measure to an energy-efficiency measure through automation)
    - Smart electrical meters to permit time-of-use pricing, providing lower rates to customers who switch their electricity use to periods when the environmental impacts are lower.

4.4 Leverage Biomass in Heating Applications

Some forms of solid biomass can be generated and used with much lower greenhouse gas emissions compared to fossil fuels, such as sustainably harvested cord wood, wood chips, and wood pellets. Solid biomass can be used to serve heating loads using stoves, furnaces, or boilers. These products can heat single rooms or entire homes or buildings. Modern wood heating systems are available today that use fully automated fuel delivery, storage, and feeding, requiring user interaction only to empty an ash bin once or twice a year in a residential application. They also achieve impressively low levels of particulate emissions—approaching the levels achieved by fossil-fuel-fired equipment.

Solid biomass poses some disadvantages, though, including:

- Traditional wood or pellet stoves and boilers (not the modern wood heating systems referenced above) emit significant amounts of particulate matter that can have adverse health effects[83]
- Requires transport, storage, and handling of bulky, solid fuels
- Requires disposal of ash.

Further, significant uncertainty and controversy exist regarding the emissions benefits of solid biomass. We make no attempt here to explore this uncertainty/controversy.

Liquid biomass fuels are also available, for example, waste vegetable oils or ethanol derived from biomass. Substantial amounts of energy are needed to grow corn (the source for 95% of the ethanol produced in the U.S.) and derive ethanol from it, which diminishes somewhat ethanol's benefits.[84] Biofuels are often blended with conventional fuels, which can also limit their impacts on carbon emissions. Some applications, however, can use 100% liquid biofuels in stationary heating applications or for transportation.

Biomass can also be used to generate both electricity and heat (called combined heat and power (CHP) or cogeneration). CHP often requires significant scale (multiple megawatts of

[83] See, for example, Sigsgaard, T., et. al; "Health impacts of anthropogenic biomass burning in the developed world"; The European respiratory journal, 46(6): 1577 – 88; December 2015. Available at: https://www.ncbi.nlm.nih.gov/pubmed/26405285

[84] Gallagher, Paul W. et. al.; *2015 Energy Balance for the Corn-Ethanol Industry*; United States Department of Agriculture, Office of the Chief Economist, Office of Energy Policy and New Uses; February 2016. See: https://www.usda.gov/oce/reports/energy/2015EnergyBalanceCornEthanol.pdf

generation capacity) to be economically feasible. Therefore, we can expect few, if any, cost-effective CHP applications in Carlisle.

4.5 Sequester Carbon and Lower Direct Emissions of Methane and Nitrous Oxide

Carbon sequestration refers to the long-term storage of carbon in plants, soils, geologic formations, and the ocean.[85] The equally important flip side of sequestration is avoiding carbon release from those same sources. Potential sequestration opportunities in Carlisle include:

- Encouraging planting and growing trees and other woody biomass (and discouraging the removal of trees/woody biomass)—see Figure 4-4
- Protecting the understory in Carlisle's wooded areas
- Considering carbon sequestration when making decisions impacting Carlisle's bog lands, wetlands, and reservoirs (such as Greenough Pond)
- Using no-till farming practices to lower direct emissions from tilled soil.

Figure 4-4: Infographic on Carbon Sequestration attached to Tree at UMass Amherst

We can also lower direct emissions of methane and other global warming gases. Natural gas consists almost entirely of methane, and some natural gas leaks into the atmosphere during extraction, transmission, and distribution. Livestock (in particular, cattle, sheep, and goats) emit methane and nitrous oxide. Methane and nitrous oxide have global warming potentials that are 28 and 265 times higher, respectively, than that for carbon dioxide.[86]

Ways to lower direct methane and nitrous oxide emissions include:

- Lowering the use of natural gas by switching to electricity (discussed in Section 4.2 above)[87]
- Fixing leaks in the natural-gas distribution system

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[85] Encyclopedia Britannica: https://www.britannica.com/technology/carbon-sequestration

[86] 100-year global warming potential for methane. From Table A1; *Statewide Greenhouse Gas Emissions Level: 1990 Baseline and 2020 Business As Usual Projection Update*; Regulatory Authority: MGL Chapter 21N, Section 3; Commonwealth of Massachusetts, Executive Office of Energy & Environmental Affairs; Department of Environmental Protection; July 2016. Available at: https://www.mass.gov/files/documents/2016/11/xv/gwsa-update-16.pdf

[87] One can argue that leakage in our existing natural-gas distribution system does not depend on how much gas we consume. While that may be true in the short term, in the long term, significant reductions in natural-gas consumption should lead to fewer distribution-system expansions and even abandonment of existing portions of the distribution system.

- Capturing emissions from livestock (cattle, sheep, and goats in particular)
- Lowering our consumption of meat and dairy products by preferring plant-based proteins.

4.6 Why is Energy Efficiency Most Important (and First)?

It might seem simpler to skip over energy efficiency and behavioral changes, and focus on electrification using renewable electricity sources. However, focusing first on energy efficiency (and behavioral changes, to the extent practical) poses several advantages (see Table 4-2).

Table 4-2: Why put Energy Efficiency First?

Advantages of Putting Energy Efficiency First
• Improved energy efficiency can ***lower the up-front costs*** associated with electrifying. For example, weatherizing a home can reduce the size and cost of the heat pump needed to heat the home.
• Improved energy efficiency can ***lower the operating costs*** associated with electrifying. For example, weatherizing a home can reduce heat loss from a home, thereby lowering the electricity costs for a heat pump to heat the home.

• While renewable electricity can greatly reduce or eliminate emissions associated with electricity generation, use of renewable electricity is not benign:
  ○ Wind and solar generation don't match the real-time demand for electricity, necessitating deployment of potentially expensive, complex, and energy-consuming storage technologies or other means to match electric supply with demand (see Appendix B)
  ○ Wind and solar are diffuse energy sources, meaning that systems:
  ▪ Require significant resources to fabricate and install [a, b]
  ▪ Cover large areas (sometimes including otherwise pristine ridgelines and coastlines) [a, b]
  ▪ Require access roads and powerline connections that can further disrupt the landscape
  ○ While the numbers are relatively small, wind turbines kill some birds and bats that fly in their paths [a]
  ○ New hydroelectric power can pose environmental impacts, including loss of land that is flooded by reservoirs, freshwater losses through evaporation from reservoirs, disturbing the habitats of fish and other aquatic life, and disrupting the recreational uses of free-flowing streams and rivers. Further, for dams that are remote from the electricity consumer, hydropower can be expensive to transmit and require significant clearing of forested areas for transmission lines.

a) Union of Concerned Scientists; Environmental Impacts of Wind Power. Available at: https://www.ucsusa.org/clean-energy/renewable-energy/environmental-impacts-wind-power

b) Union of Concerned Scientists; Environmental Impacts of Solar Power. Available at: https://www.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/environmental-impacts-solar-power.html

5 Implementing the Approach

We outline below thoughts on how to implement selected elements of the conceptual approach discussed in Section 4 above, should Carlisle decide to adopt emissions goals. We do not attempt to address herein all elements of the conceptual approach.

5.1 Types of Initiatives

Implementation will likely require a combination of municipally led initiatives and volunteer-led initiatives, some of which will require allocation of Town resources.

5.1.1 Volunteer-Led Initiatives

Examples of volunteer-led initiatives include:

- Promoting a community spirit and mindset in support of goals—both for adults and school-age children
- Providing easy access to information, educational materials, and progress-tracking summaries
- Promoting community education and outreach, including state- or utility-sponsored group-purchase initiatives (such as Carlisle's previous Solarize Mass, Solar Challenge, and HeatSmart programs)
- Promoting detailed energy assessments and energy plans for homes and other buildings
- One-on-one coaching of fellow residents to facilitate evaluating and purchasing green technologies
- Encouraging homeowners and business owners to develop energy plans.

These initiatives tend to be low cost to the community, because they are initiated, managed, and staffed largely by volunteer teams. Expenses are generally limited to small incidentals (such as printing costs for promotional materials) and incidental assistance from paid staff (such as helping to secure meeting spaces and processing expense reimbursement requests). Sometimes, volunteer teams can apply for, and be awarded, grants from state agencies that cover all or most expenses. Most grants, however, require significant in-kind contributions (staff time and/or money) and substantial ongoing reporting/administrative efforts that are generally difficult for volunteer staff to sustain.[88]

Volunteer-led initiatives tend to be non-controversial because of their low costs. However, their effectiveness is limited by:

- The availability of volunteers having the appropriate skills, aptitudes, interest levels, and time
- Lack of awareness of grant opportunities, lack of co-funding needed to secure awards, and the substantial administrative burdens associated with grant awards
- The relatively slow rate at which residents, businesses, and other organizations learn about and adopt the measures being promoted during a campaign period, which usually requires time investment, financial investment, and some risk acceptance.

As an example, the 2018 Carlisle/Concord/Lincoln HeatSmart program required over 1,000 hours of Carlisle volunteer time. By the end of the program (about 6 months duration), we secured 18 contracts to install clean heating and cooling systems in Carlisle homes (about 1%

[88] Based on 12/19/2018 discussions with Kate Hanley, Sustainability Director, Town of Concord, MA.

of Carlisle's 1680 owner-occupied homes).[89] Of course, such programs generally have spillover effects (i.e., they can encourage installations that are not directly associated with the programs) and help generate community awareness (leading to longer-term impacts), but these results suggest the challenges associated with trying to pursue emissions goals through volunteer-led approaches alone.

5.1.2 Municipally Led Initiatives

Examples of municipally led initiatives include:

- Placing sustainability front and center in municipal plans and decisions:
  - Factor in long-term energy costs and the value of carbon
  - Empower department heads to pursue sustainability, and hold them accountable
- Continuing Carlisle's Community Choice Power Supply program (see Section 2.2.6 above) with a default option of 100% renewable electricity, including shifting any remaining municipal facilities to Community Choice[90]
- Pursuing additional municipal solar projects
- Pursuing and managing government grant opportunities
- Requiring energy ratings/labels on homes and other buildings prior to ownership changes
- Revising bylaws, zoning ordinances, or change permit fees, to:
  - Encourage or require new homes and buildings to:
    - Meet passive building standards, or be zero net energy or "zero energy ready" [91, 92]
    - Be electric-vehicle ready (i.e., wired to accommodate Level 2 electric-vehicle charging stations)
  - Encourage modestly sized living units (using innovative designs to achieve excellent space utilization and aesthetic appeal)
  - Permit multi-family housing on a limited basis, including renovating single-family homes into two-family homes
  - Protect trees and other woody biomass
  - Restrict new uses of fossil fuels
- Lobbying state government for advanced building codes to promote energy efficiency and facilitate use of renewable energy in new construction and major renovations

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[89] Number of Carlisle clean heating and cooling contracts are as reported by HeatSmart installers to The Cadmus Group, and then reported to Bob Zogg, Carlisle HeatSmart Coach, by email on 09/09/2018. Number of owner-occupied homes is the estimate for 2017 from the U.S. Census Bureau, Housing, 2017 American Community Survey, Selected Housing Characteristics. See: https://factfinder.census.gov/bkmk/table/1.0/en/ACS/17_5YR/DP04/0600000US2501711525

[90] Carlisle's current Community Choice contract expires at the end of Calendar 2020.

[91] "Zero Energy Ready Home" is the U.S. Department of Energy brand for high-performance homes that are "solar ready". See: https://www.energy.gov/eere/buildings/zero-energy-ready-home

[92] The authors prefer the term "zero energy ready" over "Net-Zero Possible", the term currently used in Carlisle's Residential Open Space Community bylaw, because "zero energy ready" is well defined and enforceable, whereas "Net-Zero Possible" is not (based on our research). Reference Section 5.12.4.13; Town of Carlisle Zoning Bylaws; December 5, 2018. See: https://www.carlislema.gov/DocumentCenter/View/918/Carlisle-Zoning-Bylaws-PDF

- Working with the local natural-gas distribution company to ensure that Carlisle's natural-gas leaks are repaired
- Redistributing local taxes to approximate a carbon fee/tax (if possible). See Appendix D for further discussion.
- Developing infrastructure to support electric vehicles, bicycles (including E-bikes), and pedestrians
- Emphasizing sustainability education in school curriculums, including after-school programs
- Supporting and coordinating volunteer-led initiatives.

Municipally led initiatives include mandatory initiatives, such as regulatory policies. Mandatory initiatives tend to be more effective than voluntary initiatives because each initiative impacts virtually its entire target sector or sub-sector. They also tend to have little or no impact on town expenses. They are, however, often controversial because they can:

- Restrict the actions of residents, businesses, and organizations
- Impose up-front costs and inconveniences on residents, businesses, and organizations
- Impact property values if they are perceived to make new construction or renovations more difficult/expensive.

Some of the example mandatory initiatives listed above would require community approval at town meetings. Others will require review to determine if they would even be allowed under state regulations (such as changing how real estate taxes are assessed or changing town zoning ordinances in ways that might not be consistent with building codes).

Municipalities may also hire dedicated staff to plan, manage, and track environmental sustainability activities. Dedicated staff can often leverage their time to secure government grants that require co-funding or in-kind support. Further, dedicated staff can help organize and motivate community volunteers to improve the effectiveness of volunteer-led initiatives.

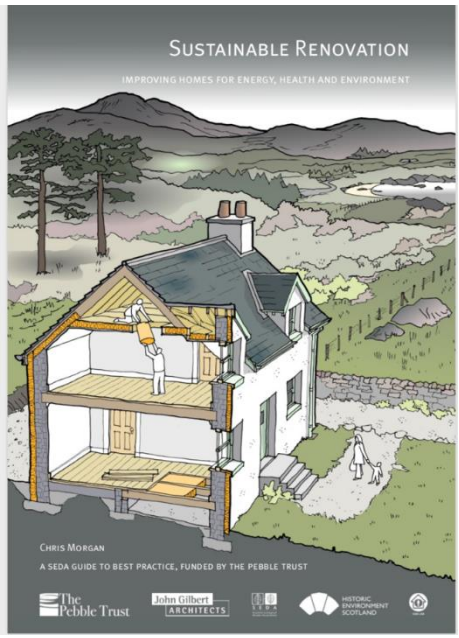
5.2 Residential Sector

Carlisle's residential sector (including motor vehicles) produces about 88% of Carlisle's direct emissions of greenhouse gases (see Section 2.1 above). We outline below suggested initiatives specifically targeting the residential sector.

5.2.1 Develop Energy Plans for Existing Carlisle Homes

A 2017 study estimates that the energy use of existing homes can be reduced by 24% on average through cost-effective measures.[93] Despite this, implementing efficiency improvements can involve significant up-front costs and be disruptive for occupants. One approach to facilitate home energy upgrades is to develop long-term energy plans for each home in the community

[93] National-average savings for single-family detached homes using measures that provide a positive net-present value (based on a 3% real discount rate, including 30 years of future cash flows). From Table A-1 and Section 2.8.1; Wilson, Eric, et al.; *Energy Efficiency Potential in the U.S. Single-Family Housing Stock*; U.S. Department of Energy, National Renewable Energy Laboratory; December 2017 (NREL/TP-5500-68670). See: https://www.nrel.gov/docs/fy18osti/68670.pdf



(see Figure 5-1).[94] As the homeowner is able and willing, he/she implements measures in decreasing order of priority. When a home changes ownership, the plan stays with the home, and the new owner continues to implement measures as he/she is able and willing. Developing meaningful energy plans will require a detailed home energy assessment—more detailed than the free assessments available through most utility programs. Costs for these detailed energy audits could be in the range of $300 to $800 per home.[95] Another source indicates that home energy assessments generally cost $150 to $275 per home.[96] Assuming homes are assessed over a 10-year period, the cost for Carlisle's 1648 owner-occupied homes would likely be in the range of $50,000 to $130,000 annually (based on the $300 to $800 range).

Figure 5-1: Free Sustainable Renovation Guide for Properties in Scotland

Costs could be paid directly by homeowners, by the Town (through taxes), or perhaps at least in part by grants or subsidies from utilities or state agencies.

A lower-cost alternative would be to develop energy plans for several types of homes (based on vintage, construction type, and other characteristics). The disadvantage is that these plans would provide less detailed guidance to individual homeowners, and would generally require some tailoring for individual homes (perhaps aided by no-cost utility energy audits, or online tools available through Mass Save and utilities).

5.2.2 Home Energy Ratings or Certifications

Analogous to fuel-efficiency ratings for automobiles, homes and other buildings can be rated based on their energy efficiency and use of renewable energy sources. Many ratings systems and green certification programs are available today, including:

- Ratings:
  - Home Energy Rating System (HERS) Index (see Figure 5-2)
  - Home Energy Score (HES)
  - Building Energy Asset Score

[94] Paul Eldrenkamp, Owner, Byggmeister Inc., Newton, MA (a design-build firm focusing on energy- and space-efficient home remodeling) discussed the concept of long-term home energy plans at the 12/06/2017 *Getting to Net Zero Public Information Session* in Lexington, MA. See video at: https://www.youtube.com/watch?v=_aE6nrEdCtc

[95] Cost range for a detailed home energy audit, as reported by the Residential Energy Services Network (RESNET). See: http://www.resnet.us/home-energy-audits-faqs

[96] Combined range for Portland, OR and Austin, TX. From "Home Energy Efficiency Policies: Ratings, Assessments, Labels, and Disclosure"; American Council for an Energy-Efficient Economy; October 2018. Available at: https://aceee.org/sites/default/files/pdf/topic-home-energy-assessment.pdf

- Green Certifications:
  - Leadership in Energy and Environmental Design (LEED)
  - ENERGY STAR Homes
  - Passive House
  - Zero Energy Ready Homes
  - National Green Building Standard
  - Pearl Home Certification.[97]

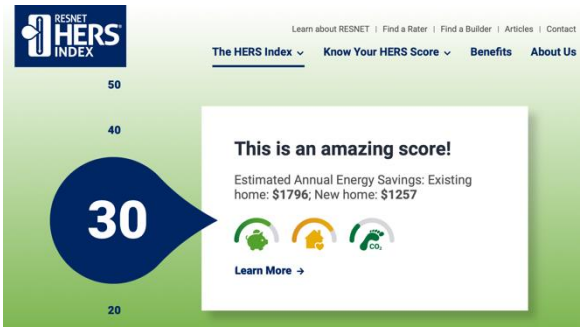


Figure 5-2: HERS Rating Score for New Construction

In addition, databases are being developed that will permit real estate agents, prospective buyers, and other interested parties to view the energy ratings and/or green certifications of homes and other buildings.[98] Green Certified real estate agents can also help residents buy or sell energy-efficient homes.[99]

5.2.3 Enhanced Regulations on New Construction and Renovations

There is no easier or cheaper time to make a home energy efficient than during its design and construction, or during a major home renovation. Enhanced regulations can be a powerful tool to help ensure that newly constructed homes achieve the highest practical levels of energy efficiency and optimum choice of energy sources. Effective January 2011, Carlisle adopted the Massachusetts Board of Building Regulations and Standards "Stretch Energy Code" for buildings.[100] Per the 2017 version of the stretch code, all new homes built in Carlisle must achieve a HERS index of 55 or less.[101]

Carlisle may be able to revise and/or add regulations[102] to include additional energy-saving measures and energy-source requirements such as:

- Restricting the use of non-renewable energy sources
- Requiring advanced heat pumps for home heating, home cooling, and domestic water heating
- Encouraging multi-family housing on a limited basis, including retrofitting existing single-family homes to accommodate multiple families

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[97] Pearl is a private certification firm based in the U.S. See: https://pearlcertification.com/
[98] One example is the Home Energy Labeling Information eXchange (HELIX) being developed by Northeast Energy Efficiency Partnerships with support from other organizations. See: https://neep.org/home-energy-labeling-information-exchange-helix
[99] The Zero Energy Project provides links to organizations that certify real estate agents: https://zeroenergyproject.org/zero-energy-home-realtors/
[100] Community Adoption of the Stretch Energy Code; "Appendix 115 AA" of the MA State Building Code (780 CMR); Massachusetts Department of Energy Resources; Updated November 14, 2019. Available at: https://www.mass.gov/doc/stretch-code-adoption-by-community-map/download
[101] "2017 Stretch Energy Code;" Massachusetts Department of Energy Resources. Available at: https://www.mass.gov/files/documents/2017/11/21/stretch-energy-code-overview.pdf
[102] We have not investigated how much latitude a municipality has to put such regulations in place. Some of these examples may be beyond the control of the municipality, especially if they are perceived to supersede or circumvent Massachusetts building codes.

- Encouraging orientations and designs that facilitate roof-mounted solar panels
- Requiring insulation, windows, and air sealing suitable for achieving net-zero (or near net-zero) energy use
- For new construction and large additions:
    - Requiring statements of embedded carbon in the materials proposed
    - Encouraging use of low-embedded-carbon materials
    - In the case of demolitions, requiring review of renovation options including embedded carbon comparisons
- Encouraging modestly sized living units (using innovative designs to achieve excellent space utilization and aesthetic appeal)
- Encouraging installation of Level 2 electric-vehicle charging stations.

5.2.4 Electric Vehicles

Gasoline consumption in vehicles accounts for about 46% of Carlisle's residential emissions (see Section 2.1.1 above). Encouraging Carlisle residents to purchase electric vehicles is essential to lowering emissions. Some of the municipally led initiatives suggested in Section 5.1.2 above (such as providing electric-vehicle charging stations) would be instrumental in encouraging electric vehicle use. Carlisle could also consider adjusting property tax assessments for homes using electric vehicles, if regulations permit.

5.2.5 Support for Behavioral Changes

One can imagine a host of initiatives and actions that would support behavioral changes to lower emissions. As few examples are:

- Establishing CrossTown Connect in Carlisle (or similar program): CrossTown Connect facilitates ridesharing/carpooling, walking or cycling to work, and use of public transportation.[103]
- Making Carlisle more bike- and pedestrian-friendly
- Providing educational programs on how to introduce more plant-based proteins in one's diet.

5.3 Municipal Sector

While representing only about 4% of Carlisle's emissions (see Section 2.1.2 above), targeting municipal energy use is important for several reasons:

- Allows Town government and departments to lead by example
- It may be easier to effect change among a relatively small group of Town representatives and staff than among the public at large, leading to more rapid emissions reductions in the municipal sector compared to the residential sector
- Provides unique opportunities for education and awareness generation
- Municipal buildings are eligible for grant monies that are not available for other sectors (most notably, Green Communities grants)

[103] For more information on CrossTown Connect, see: https://www.crosstownconnect.org/

- Lowering municipal energy use can save the Town money by lowering energy costs.

5.3.1 Establish and Maintain Accountability for Municipal Energy Use and Emissions

One approach is to hold Town departments accountable for their energy use and fuel choices (which impact emissions). Each department would have energy use targets by fuel type, and would monitor and report actuals versus targets. Department-head performance reviews would consider department contributions to meeting Carlisle's emissions goals. Departments would develop and update targets, implement energy-saving measures, and trouble-shoot problem areas. Municipal energy use and carbon emissions (compared to goals/targets) would be prominently displayed on the Town website, in total and by department, and updated at least quarterly. Each municipal facility would have an energy plan that includes buildings and vehicles. This would include developing strategies for underutilized buildings (such as the Highland Building and the Bog House) and buildings that may become underutilized (such as portions of the Carlisle Public School, depending on student enrollment trends, and the Brick Building, depending on whether Carlisle builds a community center).

5.3.2 Review Alternatives before Constructing New Buildings

Evaluate embedded emissions impacts before constructing new buildings or major additions. Consider options to re-use/renovate existing buildings to meet needs. Use low-embedded-carbon materials in all new construction or major additions.

5.3.3 Grants from Massachusetts Agencies

Through the CETF, Carlisle periodically applies for grants under the DOER Green Communities program to facilitate efficiency upgrades and use of renewable energy in municipal operations. The CETF develops grant applications and oversees implementation of approved measures in coordination with Town departments. Given the importance of these grants, it may make sense for Town staff to lead the Green Communities effort, and utilize volunteers to assist with analyses required for grant applications and manage specific projects.

As discussed in Section 7.4, the Town can also pursue a number of additional grant opportunities available from Massachusetts agencies to support communities seeking to lower GHG emissions.

5.3.4 Municipal Waste

Municipal waste disposal contributes to emissions in several ways:

- Incineration of non-recyclable trash (which includes non-recyclable items that residents do not take from the swap shed)
- Trucking of recyclable and non-recyclable trash
- Hauling of recyclable and non-recyclable trash to the transfer station by residents.

Using a Pay as you Throw (PAYT) system for non-recyclable waste disposal is a proven method for lowering waste-related emissions (see discussion in Section 2.2.7 above), and may warrant re-consideration. Encouraging more residents to participate in Carlisle's community composting program (see discussion in Section 2.2.9 above) or to compost at home would also help lower waste-related emissions.

5.3.5 Carbon Sequestration through Woody Biomass

The Department of Public Works (DPW), perhaps with assistance from the Carlisle Conservation Commission/Land Stewardship Committee, would assess and review the benefits, costs, and community impacts of promoting maintenance and growth of woody biomass (trees and shrubs) on Town-owned lands as a means to sequester carbon. The DPW would review and update this assessment at least once every 10 years.

5.4 Commercial/Institutional Sector

This sector includes commercial businesses, places of worship, other non-profit organizations, and other non-municipal / non-residential enterprises and organizations. Carlisle has a relatively small number of commercial/institutional enterprises and organizations. As for the residential sector, one approach would be to develop long-term energy plans based on a detailed energy assessment and consultation with an energy expert. Each organization would implement energy-saving measures as it is able.

5.5 Agricultural Sector

With the support of the Agricultural Commission, Carlisle's agricultural enterprises would conduct energy assessments, and develop detailed energy and carbon-sequestration plans. Cud-chewing livestock (most notably, cattle, but also sheep and goats) are key contributors to agricultural emissions. A key focus would be to employ technologies to capture and reclaim livestock emission and/or to shift from cud-chewing livestock to other types of livestock or to plant-based proteins. For example, anaerobic digesters can generate biofuels from animal waste, and those biofuels can displace fossil-fuel use.[104]

In addition to addressing livestock emissions, plan elements may include:

- Migrating to no-till agricultural practices
- Preferring perennial crops over annual crops
- Preferring crops with substantial woody biomass over those with little or none
- Improving energy efficiency of agricultural equipment
- Electrifying agricultural equipment
- Installing solar PV panels and/or wind turbines.[105]

6 Tracking Progress

Tracking progress towards goals is essential to achieving those goals. This section outlines recommended approaches to estimating annual energy use and carbon emissions associated with each sector (residential, commercial/institutional, municipal, and agricultural). More details are available in Attachments 1 to 10. Of course, the methodologies employed should be

[104] For example, see article at: https://www.masslive.com/news/2019/09/save-the-farm-save-the-environment-granville-farm-unveils-digester-that-generates-power-from-manure-and-food-waste.html?mc_cid=4a32e2030a&mc_eid=%5bUNIQID%5d&mc_cid=4a32e2030a&mc_eid=355a63d321

[105] See also Toensmeier, Eric; *The Carbon Farming Solution—A Global Toolkit of Perennial Crops and Regenerative Agriculture Practices for Climate Change Mitigation and Food Security*; Chelsea Green Publishing; 2016. Available for purchase at: http://carbonfarmingsolution.com/

improved and refined over time. When refining methodologies, historical estimates should also be updated, as appropriate, to maintain consistency.

6.1 Electricity Use Tracking

As noted in Section 2.2.6 above, most Carlisle electricity users obtain their electricity through Carlisle's Community Choice Power Supply program. Under that program, Carlisle's electricity broker provides quarterly reports indicating electricity use and expenditures by sector. Also, Carlisle's broker has provided us with reports (obtained from Eversource) showing Carlisle's annual electricity use (including customers who contract outside of our Community Choice program), broken down by rate class (residential, small commercial/institutional, medium – large commercial/institutional, and streetlights).

We suggest neglecting the carbon emissions associated with renewable energy sources.[106] For Basic Supply customers (i.e., those opting for non-renewable electricity) and those using other electricity suppliers, we suggest using the New England annual average marginal emissions rates for the local marginal unit, as published in in the appropriate version of the ISO New England Electric Generator Air Emissions Report.[107] We suggest including estimated electric grid losses (associated with electricity transmission and distribution) as published by ISO New England.[108]

6.2 Residential Tracking

Data on Carlisle's residential use of fuel oil and propane are difficult to secure. Therefore, we may need to estimate use of these fuels based on household characteristics. National Grid supplies natural gas to Carlisle, and we have had initial success in obtaining natural-gas consumption data from them.

Like many towns, Carlisle currently maintains a tax-assessment database that tracks the characteristics of each home in the community for the purposes of assessing home value, which, in turn, is used to allocate property taxes. This database records many characteristics that could be used to help estimate home-heating energy use, such as floor space (square footage), vintage, and home heating fuel and equipment type. Based on spot checks, the Carlisle's tax-assessment database has some inaccuracies in home heating fuel and equipment type, so the database may require updating/checking to use it for energy/emissions

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[106] Carbon emissions from renewable energy sources may be non-zero for the reasons outlined in Sections 4.2 and 4.6 above.

[107] For 2016, this value is 710 lb. CO_2 equivalent/MWh (0.710 lb. CO_2 equivalent/kWh), from Table 1-1; *2016 ISO New England Electric Generator Air Emissions Report*; January 2018. Available at: https://www.iso-ne.com/static-assets/documents/2018/01/2016_emissions_report.pdf

[108] For 2016, this value is 8%, from Section 1.1, Note 7 and Section 1.2, Note 7; *2017-2026 Forecast Report of Capacity, Energy, Loads and Transmission*, May 1, 2017. Available at: https://www.iso-ne.com/system-planning/system-plans-studies/celt
This loss value is for summer and winter peak demand periods. While one might expect average losses to be lower than peak losses, the Eversource Benefits Analysis model uses the peak loss value as the default value for off-peak periods as well. See Lines 40 to 43 on the Lookups tab of Exhibit 5 – 2019-20121 ADR BCR Model 2-19-19 Eversource Electric. Available at: http://ma-eeac.org/plans-updates/

estimates.[109] To estimate 2017 home-heating energy consumption, we assumed that the average Carlisle home heated with propane or fuel oil uses the same amount of energy for home heating as the average Carlisle home heated with natural gas. To estimate home-heating energy consumption for 1990, we divided Carlisle homes into three vintage categories and assumed an average "weatherization level" for each vintage. Using this method, the average home-heating energy per square foot was six percent higher in 1990 compared to 2017. We calculated home-heating energy based on the average home size in 1990, which was eight percent smaller compared to 2017.

Another useful source is the U.S Bureau of Census, which provides estimated numbers of households using various fuels for home heating.[110] We used the number of natural-gas accounts from National Grid to determine the number of homes heated with natural gas. We adjusted the number of homes heated with fuel oil so that the actual total number of homes.

For domestic water heating, clothes drying, and cooking using fossil fuels, we used various sources to estimate typical energy use. See Attachment 1 for further details.

Should Carlisle develop energy plans for Carlisle homes (see discussion in Section 5.2.1 above), those plans could also be useful in estimating fossil-fuel use in homes.

For natural gas, we recommend accounting for the climate impacts of natural-gas leakage in the transmission and distribution system. For emissions estimates reported in Section 2 above, we used a leakage estimate of 2.7%.[111] This leakage rate increases the estimated emissions impacts of natural gas by about 28% (compared to neglecting leakage impacts). This apparently disproportionate impact results because, as explained in Section 4.5 above, methane (the primary constituent of natural gas) has a global warming impact 28 times higher than that of carbon dioxide (the primary global warming gas resulting from the combustion of natural gas).

For motor-vehicle emissions estimates, we used the Metropolitan Area Planning Council's Massachusetts Vehicle Census.[112] However, this census provides vehicle data through 2014 only.

In addition to motor vehicles, Carlisle residents use gasoline and Diesel fuel in recreational vehicles, boats, emergency generators, and power tools (lawn mowers, leaf blowers, snow blowers, chainsaws, string trimmers, hedge trimmers, etc.) We did not account for these uses in our emissions analysis. While Carlisle residents can lower the associated emissions through

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[109] Based on spot checks conducted in 2015 by the Carlisle Energy Task Force. We have no reason to believe that these inaccuracies have any material impact on assessed values.
[110] See U.S. Census Bureau, American FactFinder; Community Facts, Housing, Selected Housing Characteristics. Available at: https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml
[111] *Boston's natural gas infrastructure releases high levels of heat-trapping methane*; Harvard School of Engineering and Applied Sciences; January 22, 2015. Available at: https://www.seas.harvard.edu/news/2015/01/boston-s-natural-gas-infrastructure-releases-high-levels-of-heat-trapping-methane
[112] Massachusetts Vehicle Census, Municipal Summary 2014; Metropolitan Area Planning Council. Available at: https://www.mapc.org/learn/data/

behavioral changes or by replacing power tools with electrical models (corded, or battery-powered), it may be difficult to track the benefits, except perhaps through a voluntary reporting mechanism.

6.3 Municipal Tracking

As a Massachusetts Green Communities member, Carlisle is obliged to track its municipal energy use using a web-based tracking tool called Mass Energy Insight (MEI).[113] MEI provides detailed reports on municipal energy use (based on the data that Carlisle inputs)—see Figure 6-1. We used the emissions factors shown in Attachment 3 to convert energy consumptions to the emissions reported in Section 2.1.2 above. See Attachment 3 for further details.

Figure 6-1: Example MEI Dashboards for Carlisle Municipal Buildings

The MEI does not include Carlisle's share of the emissions from the Concord Carlisle Regional High School (CCHS). The Town of Concord does, however, track and report CCHS energy use, and we based Carlisle's emissions estimates on Concord's data, which includes both building-related and transportation-related energy use. See Attachment 4 for further details.

Current estimates of Carlisle's municipal emissions include a rough estimate of emissions associated with school buses for the Carlisle Public School. Carlisle obtains school-bus service through a contracted third party. We recommend that Carlisle request fuel-consumption and/or emissions data from the contractor to improve estimates.

[113] Peregrine Energy Group, with assistance from OptiMiser LLC and UMass Clean Energy Extension, currently maintains this tool on behalf of the Massachusetts Department of Energy Resources. Authorized users can get access at: https://www.massenergyinsight.net/home

6.4 Municipal Waste Incineration Tracking

The MEI database does not include emissions associated with the incineration of Carlisle's municipal waste. We estimated these emissions as shown in Attachment 5. We recommend contacting the waste incineration plant to request plant-specific emissions data to improve these estimates.

6.5 Commercial/Institutional Tracking

As explained in Section 0 above, current commercial/institutional emissions neglect propane and fuel oil. We recommend considering a voluntary reporting program to include these estimates over time. See further details in Attachment 6.

6.6 Agricultural Tracking

Our agricultural emissions estimates are approximate only. Livestock (in particular, cattle) are responsible for most of Carlisle's agricultural emissions. However, as explained in Section 2.1.5 above, current emissions estimates for cattle vary by almost a factor of 10, which introduces significant uncertainties. We recommend further research into emissions associated with livestock (cattle in particular) in coordination with Carlisle's Agricultural Commission. See Attachment 7 for further details.

7 Cost Considerations

Establishing and pursuing emissions goals will entail costs associated with:

- Assessing community commitment
- Developing a detailed implementation plan
- Executing the implementation plan
- Purchasing equipment and services to improve energy efficiency and electrify.

7.1 Assessing Community Commitment

We are working closely with Carlisle's Master Plan Steering Committee to ensure that, in the process of obtaining community input on the broad range of topics called for in a master plan, we secure adequate input to assess Carlisle's level of interest and willingness to devote resources (time and money) to setting and pursuing emissions goals, and a clear indication of what those goals should be. We anticipate that the costs associated with gathering these inputs will be covered by the funding approved for the master plan at Carlisle's 2019 Town Meeting.

7.2 Developing Detailed Implementation Plan

Once community commitment is established, we can begin work on a detailed implementation plan. We expect that the content of this report, along with the new master plan, will provide a good starting point for developing the implementation plan. Key elements of the implementation plan will include:

- Clear articulation of Carlisle's emissions goals and timeline, as stated in the new master plan
- Updates and refinements to the implementation approach discussed herein

- Specific actions with detailed steps needed to lower emissions, including:
  - Responsible party
  - Multi-year schedule (more detailed in early years, less detail in later years)
  - Projected resource requirements, by year
- Detailed tracking procedures to monitor progress against goals
- Plan/process to keep Town officials, residents, businesses, and organizations engaged.

The detailed implementation plan may require expenditures for consultants to assist with the plan.

7.3 Executing Implementation Plan to Achieve Goals

Costs associated with executing the implementation plan will be offset to some degree by energy-cost savings (see Table 7-1 for examples), available grant opportunities, improved comfort, and peace of mind.

Table 7-1: Example Residential Cost Savings[114]

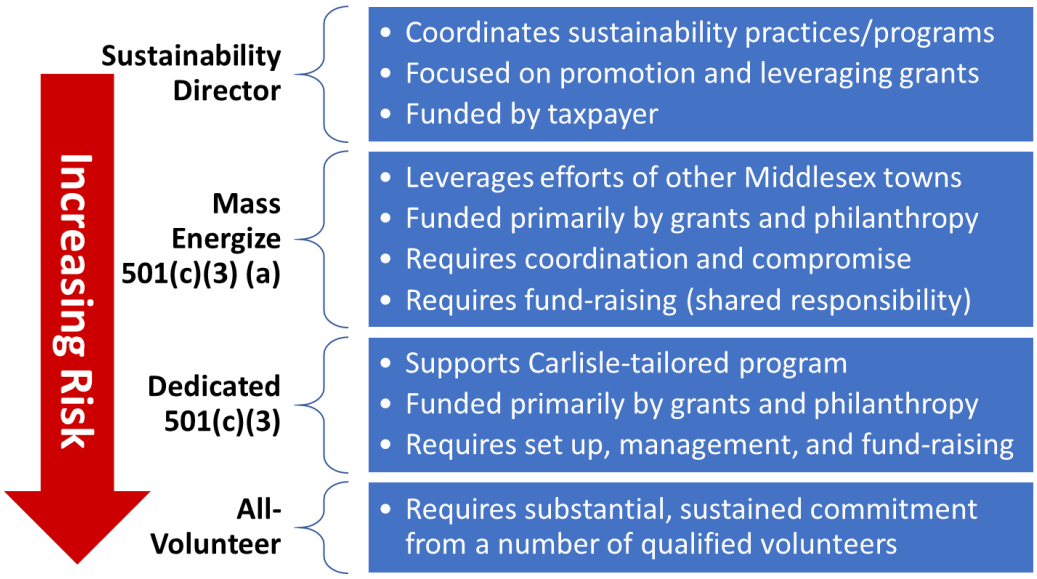
Residential Measure	Potential Community-Wide Savings ($/year) [a, b]
Weatherize Homes	Up to $1.4 million
Install Heat Pumps for Space Heating	Up to $1.0 million
Install Heat-Pump Water Heaters	Up to $0.3 million
Total Annual Savings (Residential Only)	***Up to $2.7 million***

a) As estimated by the authors. Homeowners will incur the initial costs of the measures adopted.
b) Key assumptions for upper end of range:
   a. All Carlisle homes achieve 30% reduction in home heating loads through weatherization
   b. All Carlisle homes not heated with natural gas switch to heat pumps (60% air-source heat pumps, 40% ground-source heat pumps)
   c. All Carlisle homes not heated with natural gas install heat-pump water heaters
   d. Savings based on current fuel and electricity prices, and current housing stock.

While we don't yet know the full costs associated with executing the implementation plan, those costs may include:

- Paid staff to manage various elements of the plan (see various options outlined in Figure 7-1 and Table 7-2)
- Expenses associated with website maintenance, publicity, events, etc. (included in Table 7-2)
- Costs borne by the resident, business, organization, and Town to purchase:
  - Home/building energy audits (in the range of $300 to $800 per home, as noted in Section 5.2.1 above)
  - Equipment and services to lower energy use and to convert to renewable electricity
  - Incremental costs of renewable electricity (to the extent these costs exceed the costs of the fossil fuels or non-renewable electricity being displaced).

[114] See Attachment 10 for further details and assumptions



a) The mission of Mass Energize is "[t]o provide communities with tools and resources to motivate and support their residents, businesses and non-profits in a wide array of actions to reduce greenhouse gas emissions and prepare for a changing climate."[115]

Figure 7-1: Management Options

Table 7-2: Preliminary Projected Costs Associated with each Management Option

Management Option	Taxpayer Cost ($/year) [a] Key Staff [b]	Other [c]	Total	Comments [d]
Sustainability Director [e]	$75K - $150K	$50K - $100K	$125K - $250K	Full time recommended
501(c)(3)	$0	$50K - $100K	$50K - $100K	Not recommended
All-Volunteer	$0	$50K - $100K	$50K - $100K	Not recommended

a) Estimates of the authors
b) Ranges reflect half-time versus full-time staff. Assumes employment cost (salary, benefits, and overhead) adds 46% to salary cost.
c) Includes other Town staff ($25K - $75K) and expenses ($25K)
d) Author recommendations
e) Aka, Sustainability Manager or Sustainability Coordinator.

Should Carlisle choose to adopt emissions-reduction goals and launch a community-wide campaign to reduce emissions, in our judgment:

- Organizing and managing such a campaign will require a career-track, professional Sustainability Director
- A full-time staff member (rather than half-time) is much more likely to have the commitment and motivation necessary to fulfil the requirements of this position. If cost

[115] See Mass Energize website: https://www.massenergize.org/

constraints prohibit dedicating a full-time staff member, we should hire a full-time staff member who spends part of their time addressing other town staffing needs (such as applying for and managing grants not related to climate action)

- It is not realistic to expect that Carlisle can secure adequate funds on an ongoing basis through a 501(c)(3) to maintain an effective campaign
- It is not realistic to expect that volunteers can maintain an effective campaign
- Even with the benefit of a Sustainability Director, Carlisle will need significant volunteer involvement to pursue an effective campaign.

7.4 Sources for Assistance

Table 7-3 summarizes some Massachusetts agencies that can assist communities with developing Climate Action Plans or Energy Master Plans.

Table 7-3: Planning Assistance available through Massachusetts Agencies

Agency	Planning Assistance Available
Massachusetts Clean Energy Center (MassCEC)	Clean Energy Internship Program—Typically $15 to $16/hour for 12 weeks
Northeast Energy Efficiency Partnerships (NEEP)	Community Action Planning for Energy Efficiency (CAPEE)—Provides review and guidance to communities Contact: John Balfe; 781-860-0713; jbalfe@NEEP.org
Massachusetts Climate Action Network (MCAN)	Facilitates municipal-level action on climate issues Contact: Drew Grande; 401-527-5737; drew@massclimateaction.net
Metropolitan Area Planning Council (MAPC)	Develops sustainability sections of community master plans. Typical costs range from $4,000 to $8,000. Towns can contract with MAPC without a competitive procurement process. Contact: Cammy Peterson; 617-933-0791; CPeterson@mapc.org

Table 7-4 summarizes some Massachusetts agencies that can assist communities with implementing plans to lower energy use and reduce emissions. Many grant opportunities require co-funding or services in kind (provided by paid staff).

Table 7-4: Implementation Assistance available through Massachusetts Agencies

Agency	Implementation Assistance Available
Executive Office of Energy and Environmental Affairs (EEA)	***Planning Assistance Grants*** to implement land-use regulations including reduction of land, energy, and natural resource consumption, provision of sufficient and diverse housing, and mitigation of/preparation for climate change. https://www.mass.gov/service-details/planning-assistance-grants
EEA	***Municipal Vulnerability Preparedness (MVP) Program*** provides support for cities and towns in Massachusetts to begin the process of planning for climate change resiliency and implementing priority projects. https://www.mass.gov/municipal-vulnerability-preparedness-mvp-program
Department of Energy Resources (DOER)	***Municipal Energy Technical Assistance (META)*** grants to fund independent third parties to aid municipalities in the study, negotiation, development and/or management of clean energy projects. https://www.commbuys.com/bso/external/bidDetail.sdo?docId=BD-19-1041-ENE01-ENE01-41042&external=true&parentUrl=bid
DOER	***Green Communities*** grants for qualifying communities to implement energy efficiency measures, construct renewable energy projects, or pursue other avenues to reduce their fossil fuel energy consumption. [a] https://www.mass.gov/green-communities-designation-grant-program
DOER—Proposed	If enacted, ***Green Plus Communities*** will provide grants and loans to municipalities to finance all or a portion of the costs of studying, designing, constructing and implementing energy efficiency activities. *See S.1987 (Jason Lewis) and H.2841 (Carolyn Dykema)*
Metropolitan Area Planning Council (MAPC)	***Technical Assistance Program (TAP)*** fund projects that are beneficial to the community. Eligible projects include (among many others): climate change (mitigation or adaptation); clean energy. https://www.mapc.org/about-mapc/funding-opportunities/
MA Department of Environmental Protection (DEP)	***MA Electric Vehicle Incentive Program (MassEVIP) Charging Station Programs—Fleets Charging*** provides funding for equipment and installation of fleet vehicle EVs and charging stations. https://www.mass.gov/how-to/apply-for-massevip-fleets-incentives
Massachusetts Clean Energy Center (MassCEC)	***Solarize Mass*** is a community outreach, education and group purchasing program designed to reduce cost and increase adoption of residential and small scale commercial solar systems. [b] ***Solarize Mass Plus*** pairs solar PV with additional complementary technologies such as (but not limited to) air-source heat pumps, solar hot water, and electric vehicles. https://www.masscec.com/solarize-mass
MassCEC	***HeatSmart Mass*** is a community-based outreach and education program that encourages clean heating and cooling technologies that include air-source heat pumps, ground-source heat pumps, modern wood heating, and solar hot water. [c] https://www.masscec.com/heatsmart-mass

a) Carlisle has participated in Green Communities Green Communities since 2011. See Section 2.2.2 above.
b) Carlisle participated in Solarize Mass in 2013. See Section 2.2.3 above.
c) Carlisle participated in HeatSmart Mass in 2018. See Section 2.2.5 above.

8 Risks and Uncertainties

Below we briefly summarize some of the risks and uncertainties associated with setting emissions goals and attempting to achieve those goals. In contrast, we also summarize some of the risks and uncertainties associated with taking no action.

8.1 Risks of Taking Action

Table 8-1 summarizes key risks and uncertainties associated with setting and pursuing emissions goals. While Carlisle can perhaps mitigate the probabilities and potential consequences of some of these risks, many are beyond the community's direct control.

Table 8-1: Key Risks and Uncertainties

Risk/Uncertainty	Probability [a]	Possible Consequences
Execution of implementation plan may require financial resources	High	• Increased tax burden on residents and businesses
Growing technical challenges as market demand for renewable electricity increases [b]	Low/Moderate	• Increased costs for renewable electricity
Demand for renewable electricity may catch up with supply	Moderate/High	• Increased costs for Renewable Energy Certificates (RECs) and, hence, increased costs for purchased renewable electricity
Imperfections in accounting mechanisms for tracking renewable electricity [b]	Moderate	• Purchasing renewable electricity through RECs may not in all cases increase the overall percentage of renewable electricity generated
High first costs may lead to long payback periods for investments in energy efficiency and electrification	High	• Some or many residents, businesses, and organizations may be unwilling or unable to make these investments, despite having established goals
Low current fossil-fuel prices (natural gas, in particular) impact the economics of electrification (for example, replacing furnaces and boilers with heat pumps)	High	• Some or many residents, businesses, and organizations may be unwilling or unable to make these investments, despite having established goals
Poor quality home or building energy-saving retrofits	Moderate	• Reduced energy-cost savings • Reduced reductions in emissions • Comfort and aesthetic issues
Other communities, states, and nations may not do their part	Moderate/High	• Carlisle's efforts may have little impact on climate trends
Some measures could restrict options for new home or building construction or retrofits	Low/Moderate	• Higher costs associated with new construction or retrofits • Lower property values, or slower growth in property values

a) Based on the judgment of the authors
b) See discussion in Appendix B.

8.2 Risks of Taking No Action

While taking action certainly entails risks, the risks associated with inaction may be even higher. Table 8-2 summarizes key risks and uncertainties associated with inaction.

Table 8-2: Key Risks and Uncertainties Associated with Inaction

Risk/Uncertainty	Probability [a]	Possible Consequences
Relying on individual actions alone may not result in significant emissions reductions	High	• Carlisle continues, as it has for the past 30 years, to emit greenhouse gases at the same or increasing levels
Residents, businesses, and organizations don't learn about opportunities for efficiency improvements	Moderate/High	• Lost opportunity for energy-cost savings • Lost opportunity for comfort improvements • Lost opportunity for reductions in carbon footprint
Carlisle will not set a positive example for other communities	Moderate	• Lost opportunity to influence other communities to lower their carbon footprints
Failure to make Carlisle more attractive to environmentally minded people and businesses	Moderate	• Lower property values, or slower growth in property values

a) Based on the judgment of the authors.

9 Summary

We summarize below the key messages in this report.

9.1 Carlisle's Greenhouse Gas Emissions

Figure 9-1 summarizes Carlisle's 2017 greenhouse gas emissions.

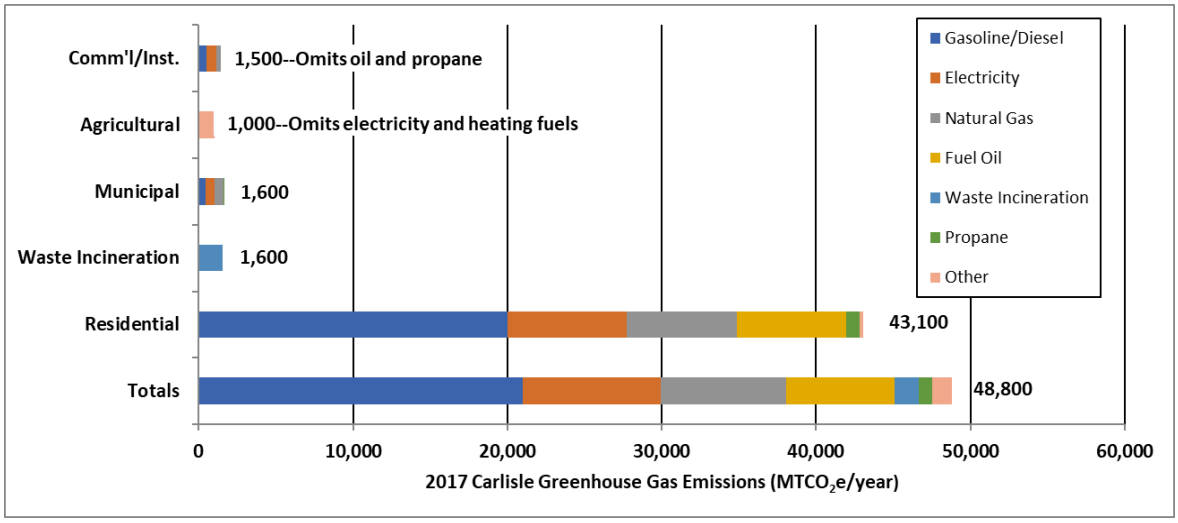


Figure 9-1: Summary of 2017 Greenhouse Gas Emissions for Carlisle

Key observations about Carlisle's GHG emissions include:

- In 2017, 88% of Carlisle's emissions were from the residential sector (including vehicles)
- In 2017, transportation fuels accounted for about 43% of overall emissions
- Carlisle's per-capita emissions are over 40% higher than U.S. and Massachusetts averages
- From 1990 to 2017:
    - Carlisle's *energy consumption* increased by about 20% with a 18% increase in population
    - Carlisle's *emissions* remained virtually the same, despite this increase in population
    - Reductions in emissions associated with the electric grid (occurring outside of Carlisle) appear to explain why emissions did not increase with increasing energy consumption. This trend does not account for the impacts of Carlisle's switch in July 2018 to a Community Choice Power Supply Program. See discussion in Section 9.2.

The emissions accounted for in Figure 9-1 above represent only about one third of Carlisle's total emissions. Embedded emissions (i.e., emissions associated with the products and services we consume) primarily occur outside of Carlisle, and are difficult to estimate and track. Figure 9-2 shows one estimate of Carlisle's total emissions.

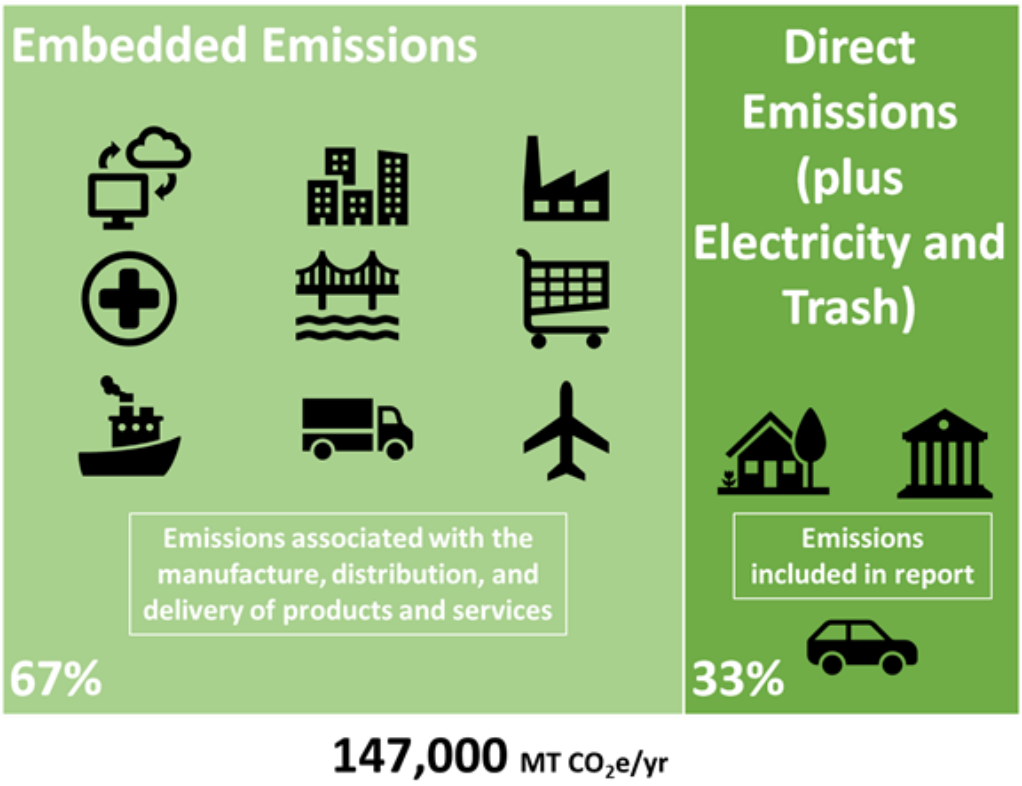


Figure 9-2: 2017 Carlisle Total (Direct and Embedded) Emissions[116]

[116] Total emissions are from U.C. Berkeley CoolClimate Calculator; as reported by Christopher M. Jones, Director of the CoolClimate Network, in a 01-24-2019 email to Debbie Bentley. We converted the

The impacts of accounting for forest/woodlands sequestration:

- Lower Carlisle total emissions by about 7% compared to a bare-ground alternative
- Increase Carlisle total emissions by about 3% compared to a fully forested alternative.

When comparing Carlisle's emissions to the Massachusetts average, accounting for forest/woodland sequestration has only modest impacts.

9.2 Carlisle's Progress to Date

Largely through volunteer efforts (primarily the Carlisle Energy Task Force and also the Carlisle Household Recycling Committee), Carlisle has taken several important steps to lower energy use and reduce greenhouse gas emissions, including:

- ***MA Green Communities Program:*** From Fiscal 2009 through Fiscal 2019, Carlisle leveraged $821,000 in state funding and utility incentives to lower municipal energy costs by an estimated $435,000 (cumulative) and municipal greenhouse gas emissions by 22%. As one of the requirements for this program, Carlisle adopted the Stretch Code (780 CMR 115.AA).
- ***Solar Photovoltaics Programs:*** Through two solar programs, we increased Carlisle's solar generating capacity to about 1,000 kW (1 MW), producing an estimated 1,500 kWh/year, or about 6% of Carlisle's electricity use.
- ***HeatSmart Program:*** Carlisle led this three-town initiative (with Concord and Lincoln) to promote installations of clean heating and cooling technologies. Under HeatSmart, Carlisle residents installed 11 air-source heat pumps and seven ground-source heat pumps.
- ***Community Choice Power Supply Program:*** In July of 2018, Carlisle entered into a Community Choice Power Supply program with a default electricity-supply option that is 100% renewable (based on purchase of Renewable Energy Certificates), dramatically increasing the portion of Carlisle's electricity secured through renewable sources. This step alone ***cut Carlisle's electricity emissions by 77% and overall emissions by 14%.***
- ***Community Composting:*** Carlisle's community composting program reduces our municipal solid waste and, in turn, reduces the Town's incineration fees, GHG emissions associated with waste incineration, and landfill requirements for incinerator ash.

Carlisle continues to work towards additional energy savings and emissions reductions through:

- ***Green Communities:*** Carlisle continues to participate in Green Communities
- ***Municipal Solar:*** Carlisle plans to install a solar canopy at the Carlisle Public School using a third-party owner/operator. Not only will this installation provide renewable electricity, but it is also expected to provide $676,000 in lease payments to the Town over the next 20 years.

calculator's per-household estimate (83 $MTCO_2e$/yr./household) to the total for Carlisle based on the number of housing units in Carlisle. Direct emissions are from Section 2.1.

- ***Trash Reduction:*** Carlisle is exploring additional options to lower municipal solid waste to reduce costs, greenhouse gas emissions associated with waste incineration, and landfill requirements for incinerator ash.
- ***Carlisle's New Master Plan:*** Carlisle has launched a master plan development process that will address environmental sustainability.

9.3 Options for Emissions Goals

Should Carlisle choose to adopt goals to lower greenhouse gas emissions, we identified two logical options:

- Align with the Massachusetts Global Warming Solutions Act of 2008 (GWSA): Lower town-wide greenhouse gas emissions by 80% by 2050 (5% average annual reduction)
- Align with 2018 recommendations of the Intergovernmental Panel on Climate Change (IPCC): Lower town-wide greenhouse gas emissions by 95% by 2050 (2017 baseline) (10% average annual reduction).

The latter option better reflects what climate scientists estimate is needed globally to limit global warming to 1.5°C and thereby avoid some of the most serious consequences of global climate change. Further, Governor Baker pledged Massachusetts to a new goal of net zero carbon emissions by 2050 at his January 21, 2020 State of the Commonwealth Address. This may lead Massachusetts to update the original GWSA goals.

9.4 Recommended Conceptual Approach

While the Massachusetts Global Warming Act of 2008 (GWSA) establishes emissions-reduction goals for the state, effectively addressing emissions associated with individuals, small businesses, and municipal operations will likely require local actions and initiatives. Should Carlisle choose to adopt emissions-reduction goals, the most effective approach will likely include:

- Improving the energy efficiency of our homes and buildings
- Electrifying (i.e., converting from fossil fuels to electricity in homes / buildings / vehicles)
- Continuing to switch to renewable electricity
- Sequestering carbon and lowering agricultural emissions, where feasible
- Promoting more sustainable behaviors.

Improving energy efficiency is the most important step in the process of lowering emissions of our homes and buildings. Simply electrifying and using renewable electricity is not sufficient.

To successfully implement this approach, Carlisle will want to:

- Hire a Sustainability Director to manage and promote the process
- Develop energy plans for existing homes and buildings
- Promote electric vehicles
- Promote home/building weatherization, followed by installation of high-efficiency electric appliances and equipment (most importantly, for home/building heating/cooling and domestic water heating)

- Consider regulations and/or permit fees that:
    - Encourage or require new homes and buildings to:
        - Meet passive building standards, or be zero net energy or “zero energy ready”
        - Be electric-vehicle ready
    - Encourage modestly sized living units (using innovative designs to achieve excellent space utilization and aesthetic appeal)
    - Permit multi-family housing on a limited basis, including renovating single-family homes into two-family homes
    - Protect trees and other woody biomass
    - Discourage new uses of fossil fuels
- Establish and maintain accountability for municipal energy use and emissions, and incorporate environmental sustainability into municipal decision-making
- Evaluate and explore new options to purchase and generate renewable electricity
- Promote broad and meaningful community engagement in the process.

9.5 Key Benefits

Should the community decide to do so, adopting and pursuing greenhouse gas reduction goals will:

- Help Carlisle residents, businesses, institutions, and municipal departments lower energy costs and reduce environmental impacts
- Improve comfort of homes and buildings
- Improve resiliency to natural disasters of homes and buildings
- Leverage funds from grant programs and utility incentives
- Encourage other communities to pursue similar goals
- Help Massachusetts achieve its emissions reduction goals
- Improve air quality
- Leave a healthier planet for current and future generations.

9.6 Key Challenges

A meaningful initiative to pursue emissions reductions will present challenges, including:

- Securing taxpayer investment for a Sustainability Director to develop an implementation plan, pursue grant opportunities, support community initiatives, manage volunteer efforts, and educate the community
- Recruiting adequate community volunteers to assist the Sustainability Director
- Exploring policy changes (such as new bylaws and zoning ordinances) that may be unpopular among some stakeholders
- Motivating Carlisle residents, businesses, institutions, and municipal departments to adopt more sustainable practices.

9.7 Next Steps

The key next steps include:

- Broadly vet the idea of setting emissions goals (and the key benefits / implications) through the new master plan development process
- If warranted by the outcome of this vetting process:
    - Incorporate emissions goals into the new master plan, along with a summary of the conceptual approach
    - Present a warrant article at the Annual Town Meeting in 2021 to secure funding for a Sustainability Director
    - Hire a Sustainability Director
    - Develop and execute an implementation plan.

Acknowledgements

The authors are grateful for the assistance provided by:

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- Drew Grande, Clean Energy Program Director, Massachusetts Climate Action Network, for identifying resources available to assist municipalities in their efforts to reduce GHG emissions
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- Kate Hanley, Sustainability Director, Concord, MA, for reviewing the report and identifying resources available to assist municipalities
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- Glenn Reed, Carlisle resident and former member of the Carlisle Energy Task Force, for reviewing the report
- Helen Young, member, Carlisle Energy Task Force, for reviewing the report
- Various additional Carlisle residents for reviewing the report, including Julie Chiappari, Frank Dolis, Dave Erickson, Mike Hanauer, Ted Shaw, and Bob Supnik.

Appendices

Appendix A: 2010 Carlisle Climate Action Plan

Carlisle Climate Action Plan (10-20-2010)

Mission statement:

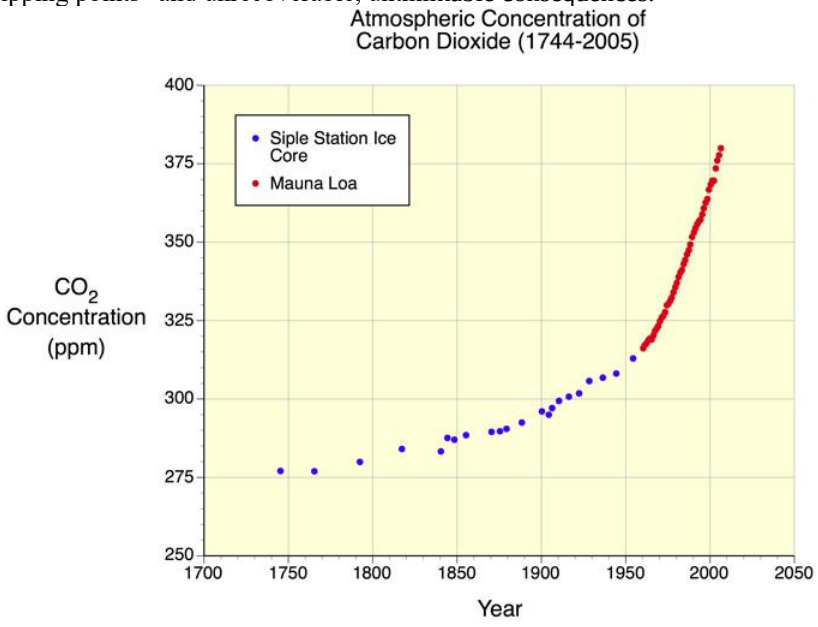
Our mission is to transition Carlisle to a "low carbon" sustainable future.

Part I, Introduction and Overview:

As a result of the combined threats of Global Warming and Peak Oil we need to do our fair share to reduce our carbon dioxide emissions and our addiction to fossil fuels.

The overwhelming majority of climate scientists after many years of ongoing studies and peer reviews agree unequivocally that the current and projected increased rate of global warming is due to our use of fossil fuels over the past 150+ years. We release several billion tons of carbon dioxide emissions annually. As a result the climate is destabilizing, lands are drying up, sea levels are rising and glacial and polar ice are disappearing even faster than predicted even just a few years ago by the IPCC.

The current level of carbon dioxide, 390 parts per million (PPM), is well above the pre-industrial range. During the past million years atmospheric carbon dioxide cycled irregularly but very slowly every hundred thousand years from 160 PPM to almost 315 PPM. During the past 10,000 years civilization developed while CO2 levels ranged between 265 PPM to 275 PPM, providing a stable climate for agriculture, cultural development, technology, learning and building permanent coastal towns and cities. You can see in the chart below how CO2 levels have climbed during the recent 200 years of industrialized growth. Before the Industrial Revolution it took about 10,000 years to change the atmosphere by 10 PPM. Today we add 10 PPM in less than 5 years. Current science estimates that 350 PPM is the highest level at which the climate might remain relatively stable but the longer we stay above 350 PPM the greater the risk of "tipping points" and unrecoverable, unthinkable consequences.

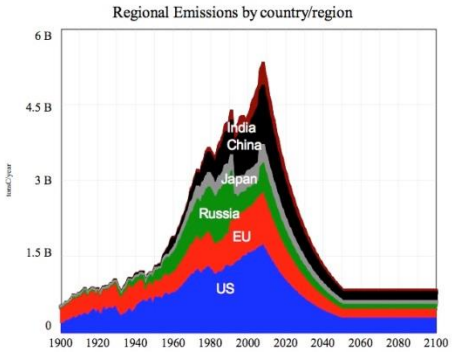


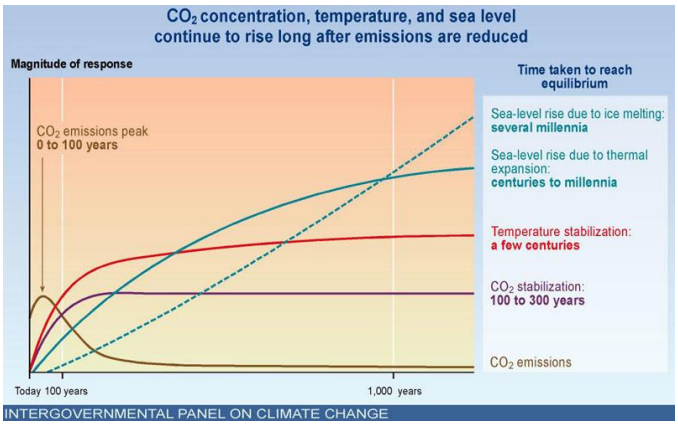
Emissions come from almost every aspect of our lives; heating and cooling our homes, electrical appliances, consumption of goods and services, lighting, transportation, waste, farming, industry, municipal buildings and infrastructure maintenance. In Carlisle, given the very small number of businesses and municipal buildings, over

90% of our emissions comes from household assets (heating/cooling systems, cars, vacation plans, diet, etc.) so most of our emission cuts must come from our households and must happen voluntarily.

We want to redouble the efforts to reduce our emissions on a per household basis in keeping with the latest scientific projections. The projected future shortage of oil, its inevitable increase in market price and its damaging impact on our ecosystems all mean we must solve our addiction to oil, coal and natural gas as soon as possible. Every day we delay is another climate disaster ensured rather than a fighting chance to survive. By doing this we will be doing our part to reduce emissions to 20% below 1990 levels by 2020 and by 80% by 2050. Emission cuts to these levels should help avoid the more devastating climate and humanitarian disasters in the decades ahead.

However even if, as depicted in the two charts below, we abruptly level off our emissions by 2015, reduce them by 20% below 1990 levels by 2020 and further reduce them to 80% less by 2050…. the planet will continue to warm, sea levels rise, oceans become more acidic and the climate continue to destabilize; just not so much.





Every little bit helps. Our excessive use of fossil fuels has created a less stable and more uninhabitable planet for everyone, especially our kids and grandkids. We need to minimize any further damage. Every nation, state, city, town and household must make every effort to do their fair share. This is especially true in the US where today our household emissions are 5 times the global average and 5 times the level we need to get to by 2050.

The Carlisle Climate Action (CCA) committee, formerly Carlisle Climate Action-Environment (CCA-E) committee was directed by the Board of Selectmen on June, 24 2008 to "form a task force right away that would at first be charged specifically with looking at energy conservation for town buildings, but would remain as a standing committee to address green buildings, capital purchases, transportation and all other energy issues going forward." The Carlisle Energy Task Force (ETF) was formed after June 2008 and has been working with the town Selectman and Planning Boards to address new construction standards and excessive energy usage in the few municipal buildings in town. This Carlisle Climate Action Plan (CCAP) has been created to supplement the efforts of the ETF and to address "***all other energy issues going forward***". The CCAP recommends ways for existing households to cut their emissions while encouraging local low-energy, low-carbon activities that can help sustain the community through a destabilizing climate, problematic economic issues and an uncertain energy future.

This CCAP in collaboration with other community groups (FRS-EAC, Middle school programs, Heet program, Sierra Club-MA, LWVCC) outlines how all existing households can and should act to bring their emissions down to sustainable levels. It provides recommendations for homeowners so they can more easily develop their own household plans that will help them select the most efficient and cost-effective alternatives. We also want to build on the many locally focused community events like Old Home Days, School and Farmer's Market activities because they provide a framework for a more resilient community.

Part II, Household and Municipal Emissions Inventory

In 2011 CCA plans to initiate a town-wide inventory of all structures. An on-line listing will allow each of the more than 1700 households and the municipal building managers to enter energy usage information from which it will calculate emissions and operational cost savings. Carbon Footprint Calculators tailored for Carlisle will also be provided on-line. This will allow us to inventory and track both individual and total town emissions so each household and facility manager can determine how best to cut emissions and make their household/facility more sustainable. This should encourage collaboration toward our common goals. The Energy Task Force will facilitate the inventory and tracking process on the municipal properties and continue to make recommendations to the town.

Part III, Recommendations

Before we can understand the magnitude of the necessary changes to our lifestyles and energy consumption we need to…

- take an inventory of our emissions and come up with a plan to cut what we can, not just what seems affordable or practical for our current lifestyles and
- fully commit to transition our households, neighborhoods and community into a more resilient and sustainable form.

The first bullet can take from 20 hours to 20 weeks; the second bullet is likely the beginning of a 20 year process.

1) **Recommendation #1, Reduce Emissions**: Use household Carbon Footprint Calculator to define the most effective ways to reduce emissions from many sources. The results may suggest you should:
    a) Change your diet. Avoid 5,000-mile salads and beef.
    b) Ride a bike, get a smaller car, drive less, carpool
    c) Fly much less, if at all.
    d) Telecommute and go on Staycations, not Vacations.
    e) Replace inefficient appliances.
    f) Add solar PV panels or windmills depending on site conditions.
    g) Super-insulate and air-seal the building envelope.
    h) Replace or upgrade your heating/cooling and hot water system(s). How?
        i) Use utility bills to estimate heating and electrical usage and future costs over the useful life of the building. Compile preliminary estimates to assess feasibility of energy efficiency upgrades.
            (1) Maximize current financial incentives and compare paybacks and IRRs. Largest energy efficiency incentives are federal tax incentives that expire in 2016.
            (2) Plan for all improvements so they are less disruptive, more efficient, performed in the proper order, sustainable and result in a better investment.
                (a) Heating (space heat and hot water) and Cooling ……(It's all about BTUs)
                    (i) Reduce Load by improving insulation levels and plugging air leaks.
                    (ii) Increase efficiency and improve air quality.
                    (iii) Research Sustainable Alternatives (solar thermal, GSHP, Biomass…)
                (b) Electricity ……(It's all about KWHrs)
                    (i) Reduce Load
                    (ii) Correct wasteful Bad habits.
                    (iii) Use Energy Star Appliances.
                    (iv) Research Sustainable Alternatives (Wind Turbines, Solar PV, Co-generation)

2) **Recommendation #2: Increase Resiliency and Localize our lives**.
    a) Reduce consumption of unnecessary Stuff and better manage our waste products.
    b) Borrow tools, share assets, buy and produce Local Foods and use Local Services. This builds skills and redundancy so that the community is more self-sufficient and able to withstand inevitable economic stresses and energy shortages.
    c) Think smaller and slower. Less is more. Unnecessary growth in terms of population, additional buildings and/or habitual over-consumption of goods and services (which depend on and increase demand for fossil fuels for production and distribution) are often harmful to the environment and increase emissions.
    d) Look for ways to collaborate with the Sustainable Concord activities.
    e) Create public transportation and bike paths to Concord center and/or West Concord.
    f) Improve recycling systems for waste products including food waste and manure management.
    g) Explore options for local Carbon Markets/Offsets that support local "green" businesses and climate friendly projects in Carlisle
    h) Explore other activities taken from the Transition Town movement.
        i) Develop visible practical manifestations of the project; It is essential that you avoid any sense that your project is just a talking shop where people sit around and draw up wish lists.
        ii) Facilitate the Great Reskilling; Give people a powerful realization of their own ability to solve problems, to achieve practical results and to work cooperatively alongside other people.
        iii) Honor the elders; Engage with those who directly remember the transition **to** the age of cheap oil.
        iv) Create an Energy Descent Plan

Part IV, Conclusion

While it is clear that we have just one planet and its finite resources cannot sustain growth beyond the level at which they can be replenished, it is not clear how we motivate ourselves locally to change and prepare for the challenges we have helped to create. This CCAP takes a direct approach in outlining the steps we must take rather than presenting the information in a way that is more encouraging and might lead many to think that sustained economic growth is possible. Currently 85% of energy worldwide is provided by fossil fuels. Even with rapid growth in all other alternative forms of energy collection, production or improved distribution fossil fuels and their damaging emissions will only be amplified by increases in housing, consumption or population. We have to slow down and soften the descent to a more sustainable future.

There are other benefits to using less fossil fuels and more of our own resourcefulness, such as:

- healthier air quality in our homes and municipal facilities,
- healthier, more secure and more vibrant neighborhoods and community,
- fewer oil wars and resultant casualties,
- lower defense related expenses to protect the transport of foreign oil,
- lower operating costs,
- more local and greener jobs,
- increased relative home values compared to non-sustainable housing/neighborhoods

These benefits added to the obligation we have to cut emissions may be enough to sustain our community.

The bottom line is…..We have to cut emissions wherever we can, not just in areas that won't cramp our lifestyles and we need to plan for and form a more resilient community. We have to do our fair share. If we chose not to then the already heavy load falls to others in the community. The earlier and more aggressively we act the greater the fighting chance we leave for our descendants and our town in the decades ahead.

Appendix

Actions that the CCA Team expects to complete by mid-2011

- Inventory of buildings
- Select or create an on-line Carbon Footprint Calculator
- Development of a Communication Plan and Training Program that:
  - coordinates with Concord and local media resources,
  - includes a website that retains all information and allows active and full participation and
  - provides workshops that educate and train residents and facility managers.
- Complete initial discussions and planning with other local and regional groups
- Begin more active discussions with public officials, working towards more complete integration with other community programs.
- Develop a Glossary of CAP terminology
- Maintain a listing of or copies of useful information and links to movies, blogs, and video clips.
  - deGROWTH and SUSTAINABILTY concepts (http://steadystate.org/discover/definition/, *Better Not Bigger*; Eben Fodor; *Beyond the Limits*, Meadows, Meadows and Randers,
  - consumption vs population growth impacts(http://earthtrends.wri.org/updates/node/79)
  - SCIENTIFIC MANDATE; ("If humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted, paleoclimate evidence and ongoing climate change suggest that CO2 will need to be reduced from its current 385ppm to at most 350ppm," writes NASA's James Hansen (2008)."
  - current CO2 atmospheric levels (http://www.carbonify.com/carbon-dioxide-levels.htm, or http://co2now.org/)
  - what towns like Carlisle can do to become more sustainable and reduce household emissions (http://www.350.org/en/workparty-ideas)
  - Union of Concerned Scientists view of adaptation for the Northeast (http://www.climatechoices.org/ne/solutions_ne/preparing-for-unavoidable.html)
  - How veterans view our addiction to oil... (http://www.operationfree.net/energy-security-threats/)

Reference Information

- Excuses for not developing a plan and acting on it.
  - I can't afford it until maybe next year;
  - I just bought a new boiler;
  - I'll wait until almost everyone else does it;
  - Technology will be better in a few years so I'll invest then;
  - I'm too busy to figure this out;
  - I have too much stuff in the attic and basement to make changes to my house;
  - I already figured out what needs to be done;
  - I heard that this green energy stuff is a waste of money;
  - Oil prices will come down again;
  - I'm saving my money for my grandkids education;
  - I'm not going to change my lifestyle so some youngster can have a better life.
  - This is too depressing, I want to talk about something else."

- State, National and International Climate Action or Energy Reduction Plans
  - March 11, 2009 Getting to Zero Final Report – MA EOEA - (http://www.mass.gov/Eoeea/docs/eea/press/publications/zneb_taskforce_report.pdf); a pathway that will lead to the universal adoption of zero net energy buildings and deep energy reduction retrofits throughout the Commonwealth by 2030
  - Massachusetts Laws, Regulations and Policies related to Climate Action
    - http://www.mass.gov/dep/air/climate/ccregs.htm
  - Copenhagen Accord
  - Clean Air Act enforcement
    - http://www.epa.gov/compliance/civil/caa/index.html

Appendix B: Challenges Associated with Reducing Emissions through use of Renewable Electricity

It is unclear how price premiums for renewable electricity might change over time. Historically, prices for renewable electricity have been trending downward, and renewable technologies continue to improve. On the other hand, a serious national effort to lower emissions would trigger rapid increases in market demand for renewable energy, which could drive up price premiums.

Renewable electricity is often purchased through Renewable Energy Certificates (RECs). RECs provide a convenient mechanism for accounting for who can legitimately claim that they are using renewable electricity when that renewable electricity is mixed in the grid with electricity from other sources. The supplier of renewable electricity can sell RECs (usually not bundled with actual electricity purchases) to those who seek credit for using the renewable electricity that the supplier generates. Some, however, challenge whether purchasing RECs actually leads to new renewable electricity resources (aka, additionality).[117] The Green Energy Consumers Alliance argues that the purchase of national RECs does not promote additionality, but that the purchase of Massachusetts Class I RECs does.[118] Colonial Power Group argues that even purchasing Massachusetts Class I RECs does not ensure additionality.[119] A further cause of confusion is that most renewable energy generators (including homeowners who have solar photovoltaic panels) sell all of the RECs associated with the electricity they generate. Many of these generators consider themselves to be using renewable energy, but such claims result in double-counting because only the purchasers of those RECs can correctly make such claims.

Another uncertainty is the cost and complexity of adapting our electricity infrastructure to manage large amounts of renewable electricity. Most renewable electricity sources are non-dispatchable, i.e., they cannot be ramped up or ramped down to match the demand for electricity. When renewable electricity is a small portion of the overall electric generation mix, this fact is of little consequence. As the fraction of renewable electricity increases, however, it becomes more difficult to match the overall electricity demand simply by ramping up and down dispatchable generation assets. Storing electricity to better match supply to demand is difficult (and expensive) using currently available storage technologies. Changing consumption patterns to better match supply is also difficult for most electricity consumers, although many electric utilities can achieve short-duration load shifts during peak-demand periods by providing various incentives to specific customer groups. However, shaving peak demand typically

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[117] See, for example: Gillenwater, Michael, et. al.; "Additionality of wind energy investments in the U.S. voluntary green power market"; Renewable Energy, Volume 63, March 2014, Pages 452 – 457. Available at: https://www.academia.edu/25967159/Additionality_of_wind_energy_investments_in_the_U.S._voluntary_green_power_market

[118] Appendix 2; Chretien, Larry, et. al.; "Green Municipal Aggregation in Massachusetts"; Green Energy Consumers Alliance; February 2020. Available at: https://info.greenenergyconsumers.org/gmareport2

[119] Section 2.4; Cappadona, Mark; Community Choice Aggregation Consulting Services Proposal (to the Town of Harvard); Colonial Power Group; April 23, 2018. Available at: https://www.harvard.ma.us/sites/harvardma/files/uploads/harvard_-_rfp_ccaggregation_colonial_power_group_non-price_.pdf

requires load shifts lasting less than one hour. In contrast, an electric grid powered by 100 percent renewable generation may require load shifts lasting several hours or more.

One approach under consideration is to leverage the electricity storage potential of electric vehicles (EVs). Under this approach, EVs would store excess electricity from the grid, or supply electricity to the grid when needed. For this to work, the EV owner would need to be compensated for providing this function. Also, sufficient EVs would need to be idle (and connected to charging/discharging stations) to provide the necessary storage capacity, and owners would need assurance that they will have adequate battery charge when they want to use their vehicles. One can imagine that the algorithms to accomplish this, let alone the technologies, would be complex.

The challenge could also be mitigated some by careful selection of the mix of renewable technologies deployed. For example, on-shore wind tends to generate more electricity at night than during the day, while solar generates electricity during the day (typically peaking at mid-day or early afternoon). Off-shore winds tend to be more consistent, and can avoid some of the volatility of on-shore sources. Also, geographic distribution of generation sources can somewhat smooth the overall generation profile of renewable sources. (The wind might not be blowing here, but it's blowing somewhere.)

Using electricity from nuclear power plants is another approach to lowering the carbon missions associated with electricity generation and use. While nuclear power plants do not emit carbon, many do not consider them to be "clean" energy sources as they require extraction, refinement, transport, storage, and long-term disposal of hazardous materials, with the associated environmental and human-safety risks.

Appendix C: Energy and Emissions Goals Established by Other Towns

The table below summarizes energy and emissions goals established by selected other towns.

Town	Acton

Goals	*Acton 2020 Comprehensive Community Plan:* Goal 2: Ensure Environmental Sustainability:
	• Objective 2.3: Reduce emissions of carbon dioxide and other greenhouse gases
	  ○ Strategy 2.3.1: Encourage use of cleaner energy sources
	  ○ Strategy 2.3.2: Reduce energy use in new and renovated buildings
	  ○ Strategy 2.3.3: Reduce energy use in existing buildings
	  ○ Strategy 2.3.4: Reduce transportation-related CO_2 emissions
	  ○ Strategy 2.3.5: Inform and educate Acton residents and businesses regarding energy efficiency
	  ○ Strategy 2.3.6: Continue planning for reducing Acton's carbon footprint
	• Approved April 3, 2012 at Town Meeting
	• http://acton2020.info/goals.shtml

Other Comments	• MA Green Community
	• Community Choice Aggregation (Acton Power Choice):
	  ○ Established in Fall 2017
	  ○ Power Choice Standard (default): Additional 5% New England renewable energy (Class I RECs)
	  ○ Power Choice GREEN: 100% New England renewable energy (Class I RECs)
	  ○ https://masspowerchoice.com/acton
	• Relevant Organizations:
	  ○ Acton 2020—Town committee tasked with "implementing the recommendations in Acton 2020's Comprehensive Community Plan."; http://acton2020.info/
	  ○ Green Advisory Board
	  ○ Green Acton (501(c)(3) non-profit organization); https://greenacton.org/
	  ○ Member of ICLEI—Local Governments for Sustainability; http://www.iclei.org/
	• 07-10-2017: Pledged support of Paris Climate Accord under We Are Still In; https://www.acton-ma.gov/ArchiveCenter/ViewFile/Item/9603 and https://www.wearestillin.com/
	• Green Advisory Board requested quotes for Carbon Neutrality Initiative; https://www.acton-ma.gov/ArchiveCenter/ViewFile/Item/10413
	• Partnered with CrossTown Connect, a Transportation Management Association: https://www.crosstownconnect.org/about#awards

Town	**Bedford**
Goals	Aligned with MA GWSA to achieve 80% reduction of GHG emissions by 2050 from a baseline to be established: • Established 11/06/2017 at a special Town Meeting (Article 2) • https://www.bedfordma.gov/sites/bedfordma/files/news/stm_minutes_nov2017rev.pdf • Appropriated $75,000 to assess Bedford's energy use and generate a report, road map, and timeline to achieve energy goals; https://www.bedfordma.gov/sites/bedfordma/files/news/stm_minutes_nov2017rev.pdf • Initial focus is on residential, commercial, and municipal buildings; https://docs.google.com/document/d/1SSfO9ZOzac28i2IdCqk_Cq7TiJtUjfARdsioWy6o2xI/edit

Other Comments	• MA Green Community
	• Community Choice Aggregation in progress:
	  ○ Developed proposed Municipal Aggregation Plan for public review
	  ○ https://www.bedfordma.gov/selectmen/pages/community-choice-aggregation
	• Relevant organizations:
	  ○ Energy and Sustainability Committee / Energy Task Force—Town Committee; https://www.bedfordma.gov/energy-task-force
	  ○ NETZERO Bedford, MA—partnered with Revise Energy to conduct home energy assessments; http://netzerobedfordma.org/

Town	**Boxborough**

Goals	*Boxborough 2030, Recommendations & Implementation Plan, A Master Plan for the Town of Boxborough, Massachusetts:* Goal 5.1. Reduce the town's overall carbon footprint: • Strategy 5.1.1. Actively explore options to adopt renewable energy generation for the town's electricity needs • Strategy 5.1.2. Promote energy efficiency and conservation measures for all buildings in the municipal, residential, and commercial sectors—targeting 20% reduction in building energy consumption • Strategy 5.1.3. Develop mechanisms to support use of alternative fuel vehicles • Strategy 5.1.4. Implement strategies to climate change resiliency an adaptation • Strategy 5.1.5. Pursue a Massachusetts Green Communities Designation • Established January 2016 • http://www.boxborough-ma.gov/sites/boxboroughma/files/file/file/boxborough2030_recommendations_and_implementation_plan_january2016.pdf
Other Comments	• Littleton Electric Light Department –Municipally owned electric utility; http://www.lelwd.com/electric-department/ • Relevant Organizations: ○ Energy Committee—charter focuses on environmental impacts, waste recycling, and municipal energy costs; http://www.boxborough-ma.gov/energy-committee-0 • Partnered with CrossTown Connect, a Transportation Management Association: https://www.crosstownconnect.org/about#awards
Town	**Cambridge**
Goals	By 2040, 70% emissions reductions through energy efficiency and increased renewable energy • Established in 2015 • City Council established Cambridge Net Zero Action Plan, which includes this goal • Roughly in line with MA GWSA goals • Applies to stationary energy use only—not transportation • http://www.cambridgema.gov/CDD/Projects/Climate/NetZeroTaskForce By 2050, achieve net zero /carbon-free status in the region • Metropolitan Mayors Coalition Climate Mitigation Commitment • http://www.mapc.org/wp-content/uploads/2017/09/FINAL-Metropolitan-Mayors-Climate-Mitigation-Commitment.pdf Note: The Sierra Club reports that Cambridge committed to 100% renewable energy ***by 2035*** • https://www.sierraclub.org/ready-for-100/commitments

Other Comments	• MA Green Community
	• Community Choice Aggregation (Cambridge Community Electricity Program):
	  ○ Effective July 2017
	  ○ Standard Green (default): 25% more solar energy than required—all from projects in or near Cambridge
	  ○ 100% Green: 100% Massachusetts renewable energy (Class I RECs)
	  ○ http://masspowerchoice.com/cambridge
	• Pledged support of Paris Climate Accord under We Are Still In; https://www.wearestillin.com/

Town	**Concord**
Goals	Aligned with MA GWSA, but with a 2008 baseline: • By 2020: 25% reduction in greenhouse gases • By 2030: 100% non-carbon-emitting electricity (not part of MA GWSA) • By 2050: 80% reduction in greenhouse gases • Authorized $100,000 for a Director of Energy (Director of Sustainability) position • Authorized additional $100,000 for a consultant to assist in formulating the plan and achieving the goals • Established in 2017 through Article 51, a citizen petition, approved at Annual Town Meeting • http://concordma.gov/2184/Climate-Action-Planning

Other Comments	• MA Green Community since 2013
	• Concord Municipal Light Plant—Municipally owned electric utility:
	  ○ November 2017 strategic plan targets reaching 100% carbon-free electricity by 2020
	  ○ http://www.concordnet.org/464/Municipal-Light-Plant

	• Relevant Organizations:
	  ○ Concord's Sustainability Division:
	  ▪ Established in 2017 to develop and implement "programs, policies and initiatives to achieve the Town's climate and sustainability goals."
	  ○ https://concordma.gov/2184/Sustainability-Goals-and-HistoryEnergy Future Task Force—Town committee:
	  ▪ Delivered final report in March 2016 recommending goals aligned with MA GWSA
	  ▪ https://www.concordma.gov/DocumentCenter/View/8474/EFTF-Final-Report
	  ○ Climate Action Advisory Board—Town committee:
	  ▪ Established "to advise the Director of Sustainability and the Town on strategic implementation of Article 51 and town-wide climate goals."
	  ▪ https://www.concordma.gov/2136/Climate-Action-Advisory-Board
	  ○ Concord Comprehensive Sustainability and Energy Committee—Town committee:
	  ▪ http://concordma.gov/907/Comprehensive-Sustainability-and-Energy-
	  ▪ In 2017, launched *Cooler Concord* to help residents learn about and take advantage of energy conservation opportunities; http://coolerconcord.org/
	  ○ Concord Climate Action Network—Local chapter of the Massachusetts Climate Action Network, a 501(c)3 non-profit organization; http://www.concordcan.org/
	  ○ Mothers out Front, Concord Chapter; https://ma.mothersoutfront.org/concord
	• Established Energy Master Plan in 2011; https://www.concordma.gov/DocumentCenter/View/3527/Concord-2011-Energy-Master-Plan-PDF
	• Sawyer Trust Fund established in 2007 for $1.7 million "to enable the Town of Concord to improve is public facilities with respect to energy conservation, water conservation, and materials recycling."; https://www.concordma.gov/DocumentCenter/View/3591/Sawyer-Trust-Fund-Application-PDF
	• Partnered with CrossTown Connect, a Transportation Management Association: https://www.crosstownconnect.org/about#awards

Town	**Harvard**
Goals	None identified

Other Comments	• MA Green Community
	• Community Choice Power Supply:
	  ○ Default option includes 100% renewable energy content (national wind RECs)
	  ○ https://colonialpowergroup.com/harvard/
	• Relevant organizations:
	  ○ Energy Advisory Committee—Town committee:
	  ▪ Focuses on municipal energy
	  ▪ https://www.harvard.ma.us/energy-advisory-committee
	  ○ Municipal Vulnerability Preparedness Sub Committee

Town	**Lexington**

Goals	"Our 25 year goal is to reduce greenhouse gas emissions from Lexington's residential, commercial, and municipal buildings and to achieve a transition to renewable energy sources."
	• Referenced at the 2017 Annual Town Meeting, which may imply that the target date for the reduction is 2042. See: https://www.lexingtonma.gov/sites/lexingtonma/files/uploads/getting_to_net_zero_tm_3-24-2017.pdf
	• The Warrant for the 2017 Annual Town Meeting (Article 19) states "The Getting to Net Zero Task Force is exploring the possibility of reducing our buildings' emissions to net zero over the next 25 to 35 years." See: https://www.lexingtonma.gov/sites/lexingtonma/files/uploads/2017_atm_warrant_final.pdf
	• Article 19 FAQ references "the Global Warming Solutions Act mandated 80% reduction by 2050," but does not explicitly express that reduction as a Lexington goal.
	  ○ Budget is $40,000 per year for 2 – 3 years. At the April 3, 2017 Town Meeting (Warrant Article 19), the second round of funding ($40,000) was requested. (We did not find documentation on when the first round of funding was approved.)
	  ○ https://www.lexingtonma.gov/sites/lexingtonma/files/uploads/getting_to_net_zero_task_force_status_and_faq.pdf
	• https://www.lexingtonma.gov/sites/lexingtonma/files/uploads/getting_to_net_zero_tm_3-24-2017.pdf

	• 2013 Town Meeting: Passed the Climate Change Warrant Article 33 to "develop and implement a comprehensive climate action plan." See: https://www.lexingtonma.gov/sites/lexingtonma/files/uploads/sustainablelexingtonarticle33small3-11-2013.pdf

Other Comments	• MA Green Community since 2010
	• Community Choice Power Supply:
	  ○ Established service July 2017 (current contract through December 2018)
	  ○ 100% Green (default): 100% renewable energy, with at least 18% from New England (5% over MA minimum), and balance from wind projects outside New England
	  ○ New England Green: 100% New England renewable energy
	  ○ Basic: Meets MA requirements for renewable energy
	  ○ http://masspowerchoice.com/lexington
	• Pledged support of Paris Climate Accord under We Are Still In; https://www.wearestillin.com/
	• Relevant Organizations:
	  ○ Energy Conservation Committee—Town committee:
	  ▪ Focuses on municipal energy
	  ▪ https://www.lexingtonma.gov/energy-conservation-committee
	  ○ Sustainable Lexington Committee—Town committee:
	  ▪ Focus—enhance Lexington's long-term sustainability and resilience in response to environmental resource and energy challenges
	  ▪ https://www.lexingtonma.gov/sustainable-lexington-committee
	  ○ Getting to Net Zero Task Force—Town committee:
	  ▪ Established to examine Lexington's baseline emissions from buildings and recommend strategies for dramatically reducing those emissions
	  ▪ In March 2017, published Lexington *Energy Inventory*: https://www.lexingtonma.gov/sites/lexingtonma/files/uploads/lexington_energy_emissions_inventory_report_3-2017_0.pdf
	  ○ Member of ICLEI—Local Governments for Sustainability; http://www.iclei.org/

Town	**Lincoln**
Goals	None identified

Other Comments	• MA Green Community
	• Community Choice Power Supply:
	  ○ 2018 Town Meeting, Warrant Article 31, voted to initiate the process
	  ○ https://www.lincolntown.org/DocumentCenter/View/35394/Article-31-Lincoln-CCA-Presentation-FINAL?bidId=
	  ○ http://www.lincolntown.org/DocumentCenter/View/35366/Motions---Final-032118?bidId
	  ○ https://lincolntv.viebit.com/player.php?hash=GMcwsQmPkz66#
	• Relevant Organizations:
	  ○ Green Energy Committee—Town committee; https://www.lincolntown.org/137/Green-Energy-Committee

Town	**Sherborn**
Goals	• None identified

Other Comments	• MA Green Community
	• Pursuing warrant article for Community Choice Power Supply
	• In process of hiring Sustainability Coordinator (up to 19.5 hours/week)—posted recruitment ad December 4, 2019
	• Relevant Organizations:
	  ○ Energy Committee
	  ○ Recycling Committee

Town	**Somerville**
Goals	By 2050: • Become carbon-neutral • Use 100% renewable energy • https://www.thesomervilletimes.com/archives/89795?mc_cid=2d9cb17e88&mc_eid=355a63d321

Other Comments	• MA Green Community
	• Community Choice Power Supply:
	  ○ Default service is 5% local renewable energy (over MA minimum requirements)
	  ○ Option for 100% local renewable energy
	  ○ https://somervillecce.com/
	• Established Somerville Climate Forward, Somerville's Community Climate Change Plan:
	  ○ Includes 13 action areas and 22 key priority actions
	  ○ https://www.somervillema.gov/climateforward
	• Planned measures: LED lighting in schools and streetlights; incentives for weatherization, lighting, heating/cooling systems; EV charging stations; encouraging biking
	• Established Green Somerville: https://www.facebook.com/GreenSomerville/
	• Holds annual SustainaVille Week to promote creating a resilient & carbon-neutral Somerville

Town	**Winchester**
Goals	Strive toward net zero greenhouse gas emissions, with a commitment to reach (2006 baseline): • 2030: 40% reduction • 2040: 60% reduction • 2050: At least 80% reduction

Other Comments	• MA Green Community
	• Community Choice Power Supply:
	  ○ Default option includes 10% additional local renewable energy
	  ○ Option for 100% local renewable energy
	  ○ https://winpowerma.com/
	• Relevant Organizations:
	  ○ Climate Action Advisory Committee: https://www.winchester.us/267/Climate-Action-Advisory-Committee
	  ○ Climate Action Plan Committee: Updating town's April 28, 2011 plan
	  ○ Energy Management Committee: https://www.winchester.us/333/Energy-Management-Committee

Appendix D: Carbon Fees

Carbon fees (sometimes called carbon taxes) are fees (or taxes) on greenhouse-gas emissions (or proxies for emissions, such as energy purchases). Carbon fees create a direct financial motivation to lower greenhouse-gas emissions. Rather than allowing individuals and organizations to pass along to others the social and environmental costs associated with their greenhouse-gas emissions,[120] carbon fees convert those costs to a financial equivalent that is paid by the individual or organization responsible for the emissions. While no precise figure can be calculated for the social and environmental costs associated with greenhouse-gas emissions, figures on the order of $40/ton of CO_2 equivalent are often used.[121] Governments may lower other taxes to render carbon fees revenue-neutral, or not change other taxes, in which case carbon fees would increase government revenues.

[120] Economists often refer to such costs (i.e., off-balance-sheet costs that are passed along to others) as "externalities."

[121] For example, Massachusetts Bill H.2810, "An Act to Promote Green Infrastructure and Reduce Carbon Emissions", would ramp up carbon fees to $40/ton over a 5-year period. Available at: https://malegislature.gov/Bills/191/HD2370
Some proposals suggest ramping up fees to the range of $100 to $160/ton by 2030. See: Center on Global Energy Policy; *New Resource Compares All the Carbon Tax Proposals in Congress Right Now*; State of the Planet, Earth Institute, Columbia University; August 1, 2019. Available at: https://blogs.ei.columbia.edu/2019/08/01/carbon-tax-comparison-congress/

Attachments

Attachment 1: Residential Emissions Estimates

Attachment 2: Overall Emissions Data and Aggregation Savings

Attachment 3: Municipal Emissions Estimates

Attachment 4: CCHS Emissions Estimates

Attachment 5: Municipal Waste Incineration Emissions Estimates

Attachment 6: Commercial/Institutional Emissions Estimates

Attachment 7: Agricultural Emissions Estimates

Attachment 8: Energy and Emissions Comparisons—Concord and Carlisle

Attachment 9: Forest/Woodlands Sequestration Estimates

Attachment 10: Financial Benefits Estimates