Belmont Climate Action Roadmap

A Belmont Roadmap for Strategic Decarbonization

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Executive Summary

This Roadmap presents an aggressive yet feasible strategy for Belmont to meet the targets of its adopted Climate Action Plan goal of reducing greenhouse gas emissions 80 percent by 2050, based on 2007 levels.

Why do we need this Roadmap?

Belmont is not making nearly enough progress toward its climate goal. This Roadmap can remedy that by (a) providing measurable interim targets to motivate near-term action; (b) identifying actions likely to have the most impact, based on the most recent emissions inventory and emerging best practices; and (c) focusing Town efforts on those identified actions, specifically on strategic electrification.

Why strategic electrification?

The short answer is that we know how to make our electricity carbon-free, but the same cannot be said for other energy end-uses. And two of those end-uses, transportation by car and home heating, make up a huge portion of our carbon footprint. If we can electrify those, we can achieve Belmont's climate goals and at the same time reduce local pollution from cars and heating fuels while generating additional revenue for our locally owned utility. This Roadmap sets a target of 2030 for half of new car purchases to be electric. For home heating electrification, the target is for heat pumps to replace half of all retiring oil heating systems by 2025. By 2032, half of all retiring gas heating systems will be replaced by heat pumps.

What about emissions from electricity?

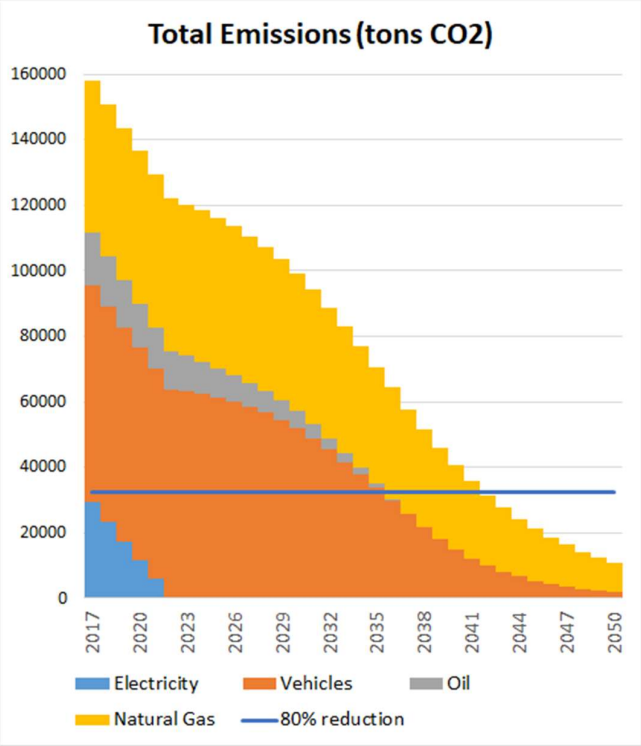
Our electricity-associated emissions go down as the New England grid becomes cleaner. Belmont can speed up its conversion to fossil-free electricity by purchasing renewable energy credits either in association with renewable energy power purchase agreements or as stand-alone credit purchases. The reason for acting quickly is two-fold: this is the easy part of reducing emissions and will rapidly help us catch up where we have lagged; and emitted carbon dioxide will begin warming the planet immediately and will remain in the atmosphere for a long time -- the sooner we act, the less damage we do. The Roadmap calls for Belmont to have 100 percent renewable electricity by 2022. Importantly, energy efficiency has a major role in making this goal affordable.

Does Belmont meet its goal if Massachusetts meets its goal?

No, Belmont needs to take action on its own. While Massachusetts also has an 80 percent by 2050 goal, that goal's achievement will not be uniform throughout the state. In fact, towns such as Belmont with their own electric utilities have so far been exempt from major renewable energy requirements. More importantly, as a small community, we can accomplish much that would be difficult at the state level. We've already proven that with the Belmont Goes Solar and Belmont Drives Electric campaigns.

What should Belmont be doing about other emissions sources?

Every bit counts. While the primary strategy involves electricity, electric vehicles, and heat pumps, broader emissions reductions will be important too. This Roadmap comes with a public participation strategy aimed at getting people thinking about other ways our choices impact emissions. Examples of topics directly related to greenhouse emissions include waste reduction, land use, housing renovations, new buildings, shade trees, air travel, food choices, and alternative modes of transportation. Some of these topics are personal choices. However, others come under the purview of various town departments and committees. Climate considerations need to be front and center in the Town's decision-making processes.



How Will Belmont Make this Happen?

Belmont's Energy Committee will facilitate a public participation process to engage Town departments, officials, committees, and volunteers in refining and providing outreach for the Roadmap. The process will culminate in approval by the Board of Selectmen and adoption at Town Meeting in 2019. The Energy Committee will work with stakeholders (particularly those identified in the public participation process as central to the Roadmap's strategy) to implement the three primary actions described here. A quarterly update to the Board of Selectmen and an annual review of emissions and progress will keep the Roadmap on track.

1. Introduction and Purpose

The Energy Committee's mission is to facilitate implementation of the town's Climate Action Plan. As such, the Committee has recently assessed the 2009 Plan's overall target and recommendations. The Committee has also reviewed more recent lessons learned by others working on reducing carbon emissions. Based on these observations and on the most recent updated carbon emissions inventory for Belmont, the Committee created this Roadmap to provide more comprehensive and structured guidance on meeting the Town's climate goals.

2. Belmont's Climate Action Plan

Belmont Town Meeting adopted the Belmont Climate Action Plan in 2009 after a rigorous and inspired town-wide process led by dedicated volunteers. At the time, surrounding communities saw the Plan as an excellent example of local action on climate. Based on a Belmont-specific emissions inventory, the Plan provided a long list of recommendations for how entities and individuals in Belmont could reduce greenhouse gas (GHG) emissions by 80 percent by 2050 (from 2007 levels). Belmont's adoption of the Plan was a strong statement that, yes, Belmont was committed to doing its part on climate and that, yes, everyone in town had a part to play.

Fast forward to 2018 and communities are feeling the urgency of climate change in a way never felt before. Already witnessing the impacts of climate change, towns and cities are committing to go fossil free and finding innovative ways to reduce emissions from all sources. More importantly, communities are developing comprehensive strategies to guide them in both the near and long terms. Like Belmont, many communities have climate targets that reflect the state's 2050 deadline for reducing emissions. But such a distant timeline provides weak incentive to take the immediate steps needed to avoid the worst effects of climate change. Indeed, just meeting these targets won't be enough for two reasons: (1) at a global level, the combined targets of nations and states are based more on political feasibility than on scientific necessity; and (2) dragging our feet and meeting the emissions target closer to the end of the timeframe, rather than the beginning, will mean far more carbon pollution accumulated over time--and it could well be too little too late.

In light of where we find ourselves, the Belmont community is going to have to pursue its climate response more aggressively if we're going to meet our climate target in any meaningful way. While we have certainly had successes and made progress in several areas (as seen in the next section), Belmont's climate response is currently piecemeal. Belmont is not going to get where we need to be at our current pace and level of effort.

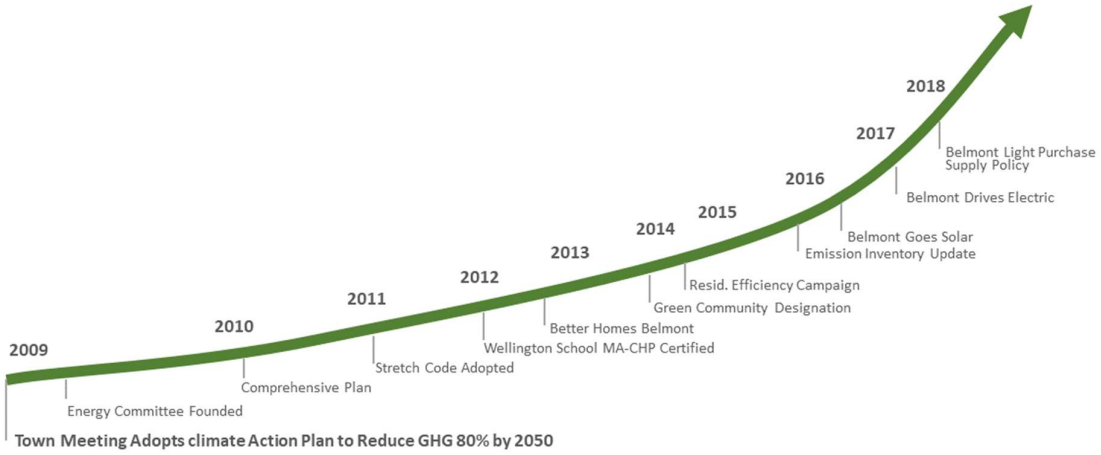
That is where this Roadmap comes in. The Roadmap will:

- Provide concrete directives with measurable results that are intended to collectively form a strategic plan;
- Focus the joint efforts of town staff, officials, volunteers, residents, and businesses on areas where they can have the most impact;
- Include up-to-date information on new technologies, policy tools, methods, and emissions data;
- Inform a stakeholder process for refining, approving, and implementing the Roadmap; and
- Make the case for integrating climate considerations into day-to-day decisions made throughout the Town.

3. Progress to Date

Belmont has multiple successes to date, thanks to the efforts of a multitude of dedicated volunteers, officials, and town staff. The timeline below shows a few of the notable achievements since adoption of the CAP.

Figure 2. Belmont's Sustainability Progress



3.1. Projects and Programs

Energy efficiency projects have featured heavily in Belmont's efforts to date. For instance, Belmont Light ran a weatherization program from 2015-2016 to help residents better insulate their homes and avoid wasted energy. In that time, the program provided grants of up to $1200 for 107 Belmont homes. Belmont Light also provides free energy audits and selected efficiency rebates. In addition, the Town hired an energy service company (ESCO) in 2006 to implement energy efficiency improvements in 12 existing town buildings. These types of projects are typically self-funded, with the hired firm paying itself back through energy savings. Belmont also included energy efficiency as a key feature in the new Wellington School building; the building process included an energy life-cycle cost analysis and modeling services to meet the state's CHPS efficiency standards, with anticipated energy savings of 48.4 percent above code.

Several successes were more systemic in nature: In 2011, Belmont joined many other Massachusetts communities in adopting the building stretch code. The stretch code requires new buildings to meet more stringent energy efficiency requirements than those in the standard state building codes. Notably, Town Meeting renewed its commitment to high levels of efficiency and sustainability when it adopted the Town's comprehensive plan in 2010. The comprehensive vision plan prioritizes reducing the Town's overall energy use for both the public and private sectors through transportation alternatives, green buildings, and local energy generation initiatives.

In more recent years, Belmont's efforts have expanded beyond efficiency through several community campaigns. Better Homes Belmont set a new record for signing up more homes as a percent of total homes in the community to receive no cost energy assessments than any other city or town in Massachusetts. Belmont Goes Solar was a volunteer-run effort to promote residential

solar installations. It worked: As of March 2018, Belmont had 290 solar installations--up from roughly 20 when the campaign started in 2016. The Town's electric vehicle (EV) campaign--called Belmont Drives Electric--has made Belmont one of the leading communities for EV uptake in Massachusetts, according to the state's EV rebate site.

One of the most critical Belmont initiatives was joining the state's Green Communities Program. Under this program, Belmont commits to reducing its municipal energy use by 20 percent over five years and to meeting other energy-related criteria. These include facilitating the siting and permitting of renewable energy, reducing emissions from vehicle fleets, and increasing the use of EVs. The Town is eligible for state grants ($250k/year) to help achieve these goals and must submit a progress report each year to the Massachusetts Department of Energy Resources. The Town's official energy reduction plan is available on the state document site.

3.2. Missed Opportunities

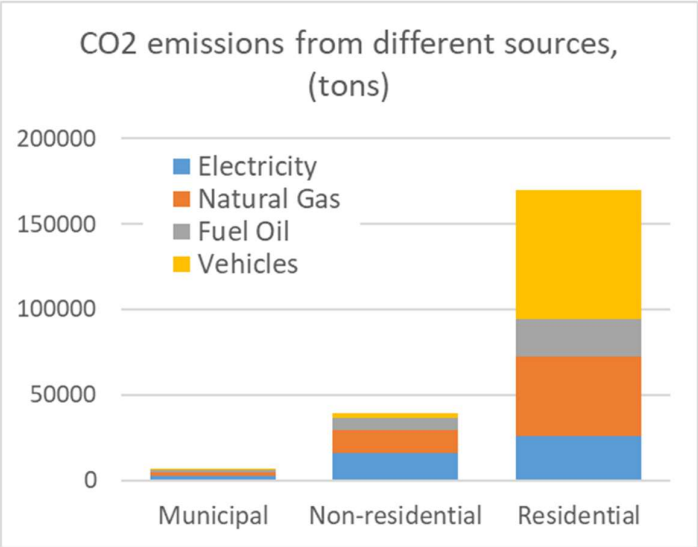
The above-mentioned progress notwithstanding, Belmont has missed out on a fair number of chances to reduce emissions. For instance, at the residential level, every boiler replaced represents a missed opportunity to reduce fossil fuel use by switching to air source heat pumps; those homeowners are then locked into fossil-burning technology for the life of the boiler. Every new home built without considering EV charging is adding to barriers to widespread EV adoption. At the municipal level, progress on solar installations was delayed due to conflicts over policy, several attempts to install solar on municipal buildings have stalled despite funding being in place, and we have a new waste management contract that does little to rein in waste production and associated emissions. While dwelling too much on these examples is not constructive, they provide a good reminder of the kinds of decisions that are directly relevant to our progress on the CAP.

3.3. Emissions Inventory

Belmont measures its progress on the Climate Action Plan by comparing carbon emissions against a baseline emissions inventory done at the time of the CAP development. The Energy Committee completed an emissions inventory update in 2016 to compare against this baseline.[1] A key takeaway from these inventories is that emissions from transportation and fossil fuels used for home and water heating are an enormous part of our carbon footprint. We cannot reach our goals without addressing these energy uses. The chart below shows the latest inventory of Belmont's emissions, broken down by sector.

[1] http://www.belmont-ma.gov/sites/belmontma/files/file/file/belmont_ghg_inventory_update_march_2016.pdf

Figure 3. Belmont emissions inventory (2014 data)



Also important is the fact that, while our electricity is getting cleaner due to the mix of resources used to power the New England grid, our overall efforts are not nearly enough. We have a widening gap between where we should be on emissions reduction and where we currently find ourselves.

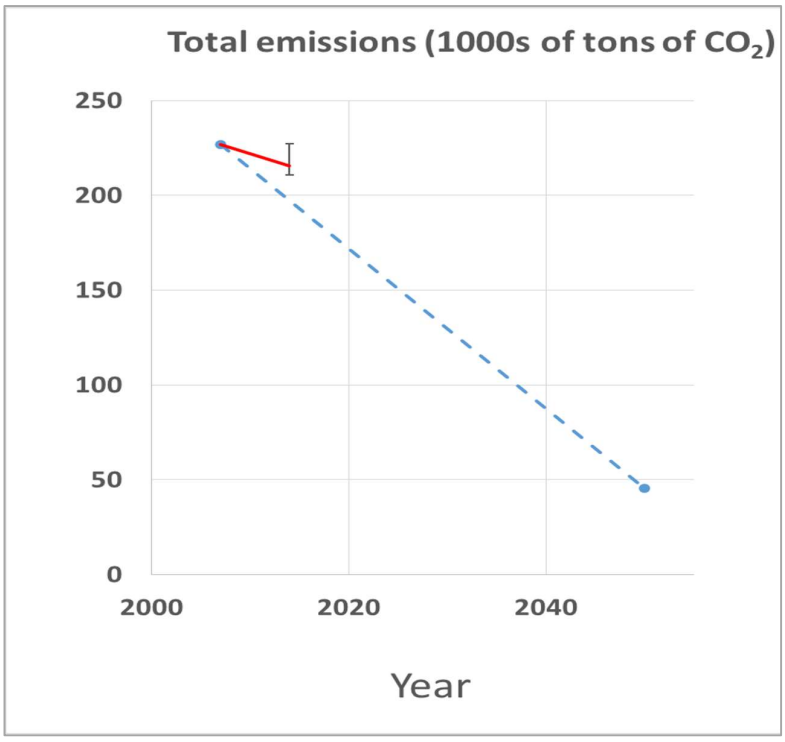
3.4. Plugging the Gap

Belmont's approach thus far has been piecemeal. Town volunteers, officials, and staff take on projects as and when they can, and without any overarching strategy to guide them. And although emissions are going down, this approach is not taking emissions down fast enough. The chart below shows the Town's emissions to date (solid line) compared to how our emissions would look if we reduced emissions to meet our target along a linear trajectory (dashed line). The key to closing that gap is to develop an aggressive strategy based on data and measurable targets. The approach described below provides just that. It also aligns with emerging best practices in climate strategies that are based on proven, available technologies and policies.

The justifications for choosing an aggressive strategy are many. Fiscal responsibility is high on that list of those justifications. Waiting to close the gap is expensive. The costs to Belmont residents and the Town only increase with every year that investment opportunities are missed. Economic studies have shown that a steady and planned approach to reducing emissions is the most cost effective[2].

[2] https://scholar.harvard.edu/files/stock/files/cost_of_delaying_action.pdf

Figure 4. Emissions reduction 2007-2014



Note: Change in Emissions from 2007 to 2014, compared to the 2050 target of 80 percent reduction in emissions. The error bar represents likely range of uncertainty in 2014 estimate. From the Belmont GHG Inventory Update.

4. Time for a New Strategic Approach

Belmont's carbon emissions largely derive from transportation and home heating. Currently, the vast majority of both transportation and heating relies on direct combustion of fossil fuels: gasoline and diesel in cars and trucks, and natural gas and oil for heating (Figure 2).

To reach Belmont's climate goal, transportation and heating must become fossil fuel-free.

Specifically, there is an emerging consensus that electrification of both transportation and home heating is the most likely path to reach our long-term climate goals.[3] Why? Simply put, there exists a path to zero-carbon electricity through multiple existing technologies such as wind, solar, and others. While the appropriate mix of technologies remains an open question, there exist technically and economically feasible options. In contrast, fossil-fuel driven technologies like gasoline-powered cars can never get to zero emissions. Incremental gains in efficiency using fossil fuel-based technologies will simply not be enough to get us where we need to go.

Thus, a strategic framework for this plan consists of two necessary and interdependent components:

- Electrify transportation and heating
- Move Belmont's electricity to carbon-free sources

4.1. Transportation

The move away from the internal combustion engine has already begun, and Belmont's high rate of adoption of EVs makes it a leader in Massachusetts. The ongoing Belmont Drives Electric initiative has been helping to move this forward.

Growth in EV sales is robust today and will increase as many automakers announce their intentions to move increasingly or entirely into selling EVs. A Bloomberg New Energy Finance forecast predicts that EVs will represent over half of new sales in the United States by 2033.[4] EVs already accounted for over half of new vehicles sold in Norway in December 2017.[5] Belmont should aspire to an aggressive timeline for EV adoption, particularly in light of its current status as a leader in Massachusetts. We propose the following ambitious but achievable goal:

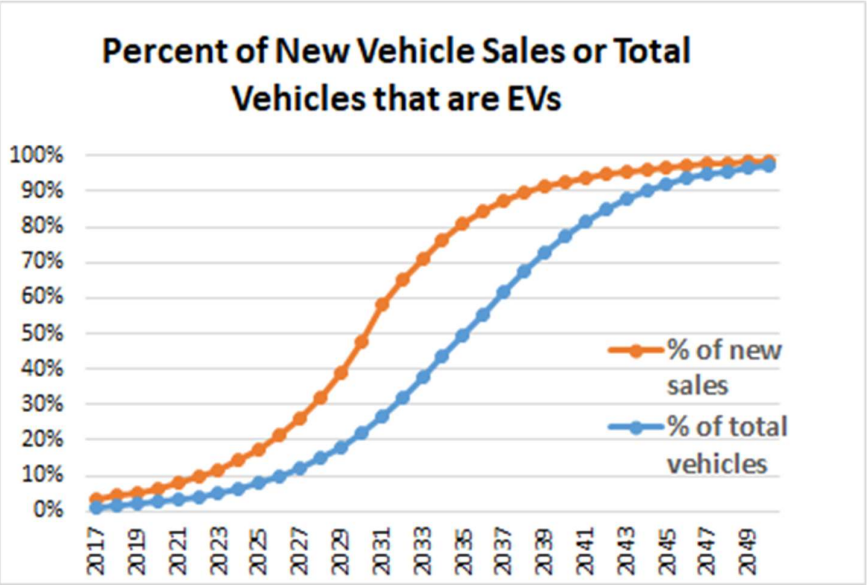
Goal: 50% of new vehicles purchased or leased in Belmont will be EVs by 2030.

Figure 4 shows a trajectory for EV adoption that reaches this goal. We assume that there will be a continuing increase in the rate of adoption of EVs between now and 2030 as the availability of different EV models increases and as declining battery costs improve prices. On this path, we would see roughly 10 percent of newly purchased vehicles being EVs by 2023.

[3] See https://www.vox.com/2016/9/19/12938086/electrify-everything and references therein
[4] https://about.bnef.com/electric-vehicle-outlook/

[5] https://electrek.co/2018/01/03/electric-car-market-share-norway-tesla-record-deliveries/

Figure 5. EV adoption trajectory



Note: The top curve shows the fraction of new vehicle sales that are EVs. The lower curve shows the fraction of total vehicles that are electric, assuming that vehicles are only replaced at the end of an 11-year lifespan (Belmont's average vehicle lifespan).

Our car purchases matter

The choice of a new vehicle is a crucial moment of opportunity for emissions reduction. Each person in Belmont who owns or leases a vehicle has a role to play in this transition. Vehicles have a long lifespan; in Belmont they are driven on average for 11 years.[6] Thus, every time someone in Belmont decides to buy a new fossil fuel-powered vehicle, that new car will be on the road polluting for over a decade. Belmont cannot be successful in meeting its CAP goal unless households strongly consider EVs every time they buy or lease a car.

EVs are a good choice right now

EVs, when powered by carbon-free electricity, provide transportation free of carbon pollution. However, even before we reach the goal of fully carbon-free electricity, switching to EVs results in an immediate reduction in overall carbon emissions. This is true even when charging vehicles using an electricity mix where combustion of natural gas underlies much of electricity production. This is because EVs are much more energy efficient than internal combustion engines. An EV converts the energy stored in a battery into forward motion of the vehicle more efficiently than an internal combustion engine, which wastes most of the energy stored in gasoline as heat. These immediate reductions in emissions provide an added argument in favor of moving to EVs as quickly as possible.

[6] From data in the GHG Inventory update.

What can the Town do to support the transition to electric zero-emission vehicles?

Public Education

In light of the fact that EVs are still an unfamiliar technology for most people, one important need is for public education about the many advantages of driving electric. These are not limited to the climate benefits; other benefits include a superior driving experience and lower operating and maintenance costs. The Belmont Drives Electric campaign is already successfully undertaking this outreach (belmontdriveselectric.org).

Belmont Light

Introduction of time-of-use pricing for electricity by Belmont Light would be a win-win for both EV drivers and Belmont Light ratepayers. By incentivizing EV drivers to charge their cars overnight when demand is low, the utility gains revenue. This would in turn help bring down rates for all ratepayers. At the same time, EV drivers are rewarded with a discount. Installation of more public charging stations would benefit both EV drivers and local businesses who could see increased patronage as people visit their establishments while charging.

Town Meeting

Town Meeting has a role to play in setting standards for the construction of housing and other buildings in Belmont. When new construction occurs, the design of such construction should not lock in existing vehicle choices. Just as Belmont has imposed substantial restrictions on the aesthetics of new housing construction, it should impose environmental constraints as well. New housing construction, for example, whether single-family or multi-family, should be designed to allow for EV charging. New parking facilities, whether public or private, should also feature adequate charging stations to support a large and growing EV population.

4.2. Heating

Efficient electrification of home heating will require switching to heat pumps.

Adoption trajectory

How quickly could we see significant penetration of heat pumps for home heating in Belmont? A recent report from Synapse Energy Economics considered the potential for Strategic Electrification in the Northeast.[7] In its "Plausibly Optimistic" scenario, heat pumps will represent half of market share of replacements of oil heating systems by 2025, and they will reach 50 percent of market share for replacement of natural gas systems by 2032. The longer timeframe for replacement of gas with heat pumps reflects the fact that heat pumps already provide an attractive direct economic benefit when switching from oil; the situation for natural gas is more challenging (see below).

Goal: 50% of replacements of oil heating systems will be heat pumps by 2025.

Goal: 50% of replacements of natural gas heating systems will be heat pumps by 2032.

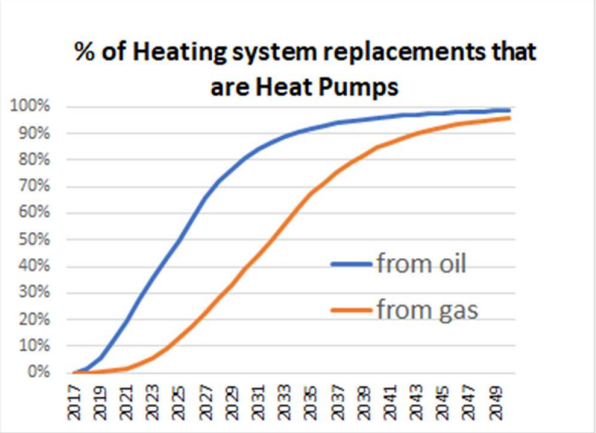
[7] http://www.synapse-energy.com/sites/default/files/Strategic-Electrification-Regional-Assessment-17-018.pdf

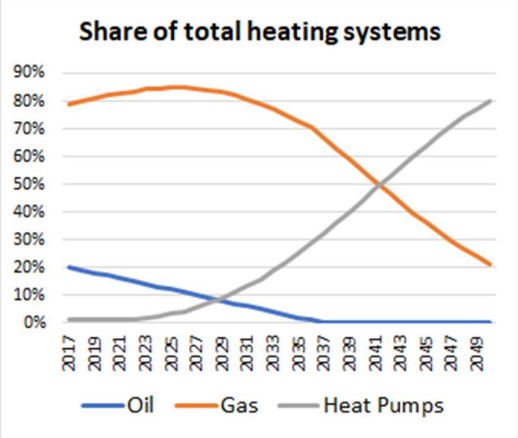
What is a heat pump?

In the past, "electric heating" has generally meant *resistive* heating, where electricity is used to directly produce heat (as in a toaster with a hot filament or a typical baseboard heater). In contrast, a heat pump does not create new heat; it simply moves heat around. Refrigerators and air conditioners are both heat pumps: they move heat, respectively, from inside the fridge out into the kitchen, or from inside the house to the outdoors. Heat pumps can also be used to work in the opposite direction to provide home heating, by moving heat from outside to inside. (It may not be obvious that there is heat to be obtained from the air outside in winter, but there is!) A key point is that it takes much less energy to move heat from one place to another (by pumping a refrigerant which is compressed and allowed to expand) than it does to create new heat. This makes heat pumps more energy-efficient than heating with natural gas or old-style resistive electric heating. Even more importantly, heat pumps can provide emissions-free heating when powered by carbon-free electricity.

Heat pumps can use either the ground or the air as the source (or sink) for heat. Ground-source heat pumps, while very efficient, are expensive to install and require adequate land area. Air-source heat pumps are much less expensive to install and can operate in a modular fashion (heating and cooling different regions of a house). While earlier models of air-source heat pumps were limited in their ability to work in cold New England winters, current models are effective well below zero degrees F, and cold weather performance continues to improve.

Figure 6. Trajectories for adoption of heat pumps. (A) Fraction of replacements of oil heating systems (blue line) or natural gas heating systems (orange line) with heat pumps. (B) The share of total heating systems that results from heating systems assumed to be replaced only at the end of a 20-year lifespan.





Challenges:

While heat pumps provide a path to emissions-free heating, widespread adoption faces several key challenges.

Slow turnover of heating systems

Heating systems last a long time -- often more than 20 years. Thus, even more so than with vehicles, the decision to replace a heating system has long-term consequences. *Installation of a new heating system powered by natural gas locks in decades of further carbon emissions*.

Policy disincentives

Along with the longevity of heating systems, existing policies and conventional thinking on energy efficiency can be problematic, working against a move to electrification. Energy efficiency incentives have historically been structured to favor a shift from fuel oil for heating to natural gas. While such a shift can result in a reduction in emissions relative to a status quo of fuel oil, natural gas is a still a fossil fuel, and its combustion still produces carbon pollution; leakage of the potent greenhouse gas methane in the natural gas extraction and distribution system further worsens its climate impact. To achieve the deep emissions reductions required to reach our Climate Action Plan goal, we need longer-term thinking.

Economics

Perhaps the major challenge for widespread heat pump adoption is that for now natural gas prices are low, making it hard for heat pumps to compete. Until gas prices either demonstrate their earlier volatility or start to include the costs that are currently externalized, we need better incentives for large-scale uptake of heat pumps. It is difficult to persuade homeowners to take on an unfamiliar technology if the financial incentives work against that adoption, despite the possible climate benefits.

What can the Town do?

Public Education. The public likely has even less awareness about heat pumps than about EVs, the latter being much more visible. Home heating systems are often replaced only in the emergency situation where the existing system has burnt out. This is not a situation conducive to careful decision-making and adoption of new, unfamiliar technology. Moreover, extensive weatherization will likely be necessary to implement along with installation of heat pumps to achieve an effective heating solution. Thus, residents need to be educated about all these issues (and motivated to take action) *before* finding themselves in the situation where replacing their fossil-fuel based system is an emergency.

Identification of trusted installers, and integration of planning of heat pump installation with energy assessments and weatherization would also be a helpful component of public outreach.

Belmont Light

Several possible avenues exist whereby Belmont Light could facilitate greater adoption of heat pumps. Notably, by switching energy use from fossil fuels to electricity from Belmont Light, customers would be keeping their ratepayer dollars local rather than supporting fossil fuel operations in distant regions.

- **Direct incentives**. BL has an existing Heat Pump program that offers incentives for air-source heat pump installation. The size of these incentives could be increased.
- **Leasing**. An alternative possibility that may lower barriers for homeowners would be to introduce a heat pump leasing program wherein BL would be the owner of the systems. Green Mountain Power in Vermont operates such a program.
- **Group purchasing**. The HeatSmart Mass program is a community-based education and group purchasing program that supports the purchase of heat pumps; it was recently launched as a pilot in seven Massachusetts communities. Participating in such a group purchase program could help facilitate adoption of heat pumps in Belmont.
- **Rate structures**. An Efficient Electric Heat Rate is offered by Great Lakes Energy, providing consumers a direct rebate on the portion of their electricity consumption used to power heat pumps. Time-variant pricing could also allow a win-win for air source-heat pump users and BL's ratepayers. Timing of operation of heat pumps could be used for demand management, allowing homeowners to use their house's thermal load as a form of energy storage that could be managed to shave peaks of electricity demand, to the benefit of all BL ratepayers. In return for providing this valuable service, heat pump users could receive a discounted rate on their electricity.
- **Disincentivizing conventional air conditioners**: Belmont Light could encourage heat pumps (above) and simultaneously discourage traditional central AC systems. HPs serve the same purpose as central AC systems, but also provide heat in the winter. As such, they could be good to adopt in homes that are installing or replacing central AC systems.

Public buildings and other new construction

As Belmont moves forward with new public building construction, the strategic electrification of those buildings and facilities should be a primary consideration. This includes heating/cooling, kitchen facilities, and hot water. Belmont Light should be regularly consulted on new facilities including not only purely public facilities (e.g., the High School), but on public/private facilities (e.g., a possible new skating rink). The town could also explore the possibility of requiring electrification in the permitting of new construction by the private sector.

<u>Heating of hot water:</u>

Gas-powered hot water heaters do not contribute as much to Belmont's CO_2 emissions as space heating, but they are still a significant source of emissions. One technology that provides hot water with no resulting emissions is solar hot water: a system that captures heat from sunlight and circulates the thermal energy to your water tank. Alternatively, heat pump electric water heaters allow efficient electrically-driven water heating. As with air source heat pumps used for space heating, heat pump water heaters work by moving heat from the room into the water tank. They can provide an almost drop-in replacement for old electric resistance water heaters, but are two to three times more energy-efficient.

4.3. Making Belmont's Electricity Carbon-Free

Strategic electrification of transportation and heating is one half of the solution to meeting Belmont's carbon reduction goals. The other necessary part is to obtain our electricity from carbon-free sources. Belmont has the great advantage of having a municipally-owned electric utility. This means the Town can make decisions about the sources of its electricity that support achieving its climate goals.

The electricity grid as a whole will need to continue to move toward carbon-free sources in order to support the transition to a carbon-free economy. By moving its electricity consumption to carbon-free sources as quickly as possible, Belmont can and should be a leader in this transition. Concord and Hingham provide noteworthy examples of nearby communities that, like Belmont, have Municipal Light Plants, and that have recently undertaken to move rapidly to 100 percent emissions-free electricity.

We propose that Belmont should obtain **100 percent of its electricity from carbon-free sources by the year 2022**, with the fraction of carbon-free electricity increasing annually until this goal is reached. The carbon-free nature of Belmont's electricity will be ensured through acquisition of the necessary clean energy credits under the Massachusetts Clean Energy Standard[8]. This standard allows credit to be claimed for low-carbon electricity either produced within New England or directly delivered to it. Acquisition of such credits is an essential mechanism to ensure that carbon-free electricity is properly accounted for and not counted twice by different consumers. Local generation of carbon-free electricity (e.g. from solar) could also play a role in satisfying some of Belmont's demands for carbon-free electricity, provided that the clean energy credits arising from that generation are retained by the town or its residents.

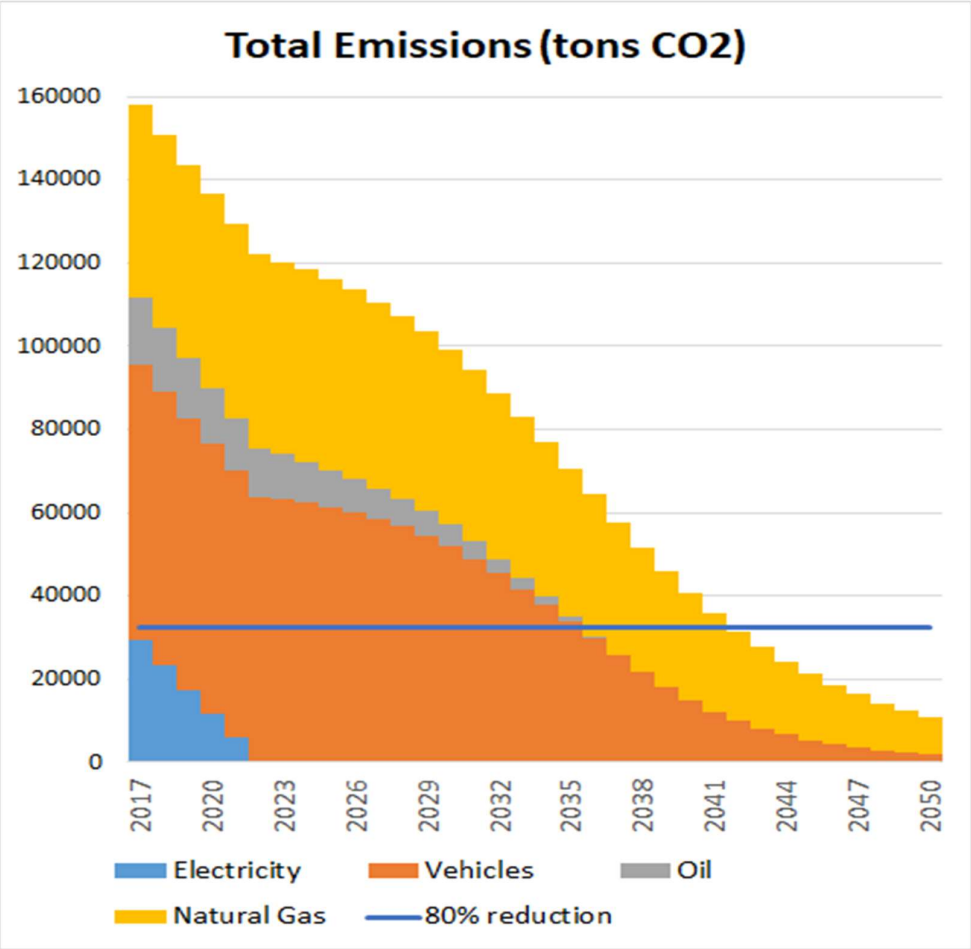
Summary of Strategic Electrification goals

1) **50% of newly purchased vehicles are electric by 2030**
2) **50% of new heating systems are heat pumps by 2025 (for replacement of oil systems) or 2032 (for replacement of gas systems)**
3) **Belmont's electricity is completely carbon-free by 2022.**

Based on meeting these goals, we project the following pathway for future emissions from Belmont's residential sector (the source of most of Belmont's emissions), showing the evolution of emissions from each source over the period 2017-2050 (Figure 7). The combination of strategic electrification and a shift to carbon-free electricity is sufficient to achieve Belmont's goal of an 80% reduction in emissions by 2050 (shown by the line).

[8] https://www.mass.gov/guides/clean-energy-standard-310-cmr-775

Figure 7. Emissions trajectory for Belmont's residential sector, 2017-2050



Note: Based on metric tons of CO2 emitted from each source. The dashed line indicates an emissions level that represents an 80 percent reduction in emissions from 2007 levels.

4.4. Energy Efficiency

The framework outlined above focuses on the twin goals of electrification and zero-carbon electricity. This focus should, however, in no way be taken to suggest that strategies to reduce overall energy consumption are not still vitally important. In transportation, this would mean those choices that result in people driving fewer miles – e.g. taking public transit, walking, biking, or carpooling. In home heating this would mean better insulation and use of smart thermostats. In electricity use, it would mean efficient appliances (e.g., refrigerators, dishwashers, and LED lights).

But why is energy efficiency important, if we plan to eventually meet all our energy needs with carbon-free electricity anyway?

First, there are considerations of cost. Using less energy saves money. As we increase the total amount of electricity we use due to strategic electrification, as well as the portion of carbon-free energy in our electricity mix, energy efficiency helps reduce the amount of electricity we will have to buy, resulting in cost savings for Belmont households. Thinking more broadly, moving electricity production for the entire New England region to carbon-free sources will be an enormous

undertaking, and the lower that each community can keep its overall electricity demand, the easier it will be for us collectively to make this massive transition.

Second, extensive weatherization (increased efficiency in home heating) will likely be necessary to make it possible for heat pumps to fully meet our heating needs. We will need to think of improving energy efficiency in homes and heat pump installation as one integrated process.

Finally, while our goal is to ultimately move to a future where our energy needs are met without causing carbon emissions, this is a transition that will take decades to complete, even with ambitious timelines for electrification. Until we get there, we will still be producing carbon pollution, and the more we can reduce our cumulative carbon emissions, the more we can reduce our overall impact on the climate (see Appendix A). Every single instance of greater efficiency in energy use helps with this overarching goal of minimizing climate damage, the motivation behind the Climate Action Plan.

4.5. Other areas of emissions reductions

In considering Belmont's CO_2 emissions, the Climate Action Plan, the CO_2 Inventory Update, and this strategic roadmap all restrict the scope of their analyses to considering either direct emissions of carbon pollution that occur through combustion of fossil fuels here in Belmont, or those emissions that result from generation of the electricity used in Belmont.

However, we cannot avoid the fact that the choices of Belmont's residents affect overall global carbon emissions in many indirect ways as well. For one thing, everything we purchase – food, clothing, household items – has an associated carbon footprint incurred during its path to market. The Center for Global Development estimates that the indirect carbon footprint associated with a typical American's consumer choices is comparable in size to her direct carbon footprint.[9] Thus, if residents of Belmont want to minimize their overall impact on the climate, there are many other areas in which their decisions matter beyond their choices of vehicle, heating system, and electricity source, and the efficiencies with which they use those technologies.

Some key areas include:

Air travel. Air travel by Belmont residents was not included under Transportation in the CAP or the CO2 emission inventory update, due to the difficulty in obtaining the relevant information. However, flying is very carbon-intensive, and there are likely many Belmont households for which air travel represents a large fraction of their overall carbon footprints -- in many cases, larger even than home heating or personal vehicle use.

Waste. Belmont currently sends its waste for incineration; combustion of the waste results in CO_2 emissions. The heat produced is used for electricity generation, which does provide some economic benefit; however, since burning municipal waste creates more emissions per unit of energy produced than does combustion of the competing fossil fuel, natural gas, incineration of waste leads to an overall increase in CO_2 emissions. Increased diversion of waste by recycling or composting will reduce these associated emissions. Curbside composting by residents via the Belmont Composts! campaign will help with this.

Food choices. Consumption of beef in particular has a large associated climate impact.

[9] https://www.cgdev.org/sites/default/files/who_pollutes_greenhouse_gas_footprint_0.pdf

To give a sense of scale for climate impacts, the chart below compares the approximate annual CO2 equivalent emissions associated with different activities based on the following scenarios:

Air Travel: **one** round-trip flight from Boston to San Francisco for a family of four
Beef: a household of four people, each eating the average American intake
Waste: typical emissions associated with waste for a Belmont household
Electricity: typical MA household consumption using current sources of electricity
Driving: 8000 miles driven per year in a 29 mpg gasoline-powered automobile
Natural Gas: average usage of gas for a Belmont house of size ~2400 sq. ft

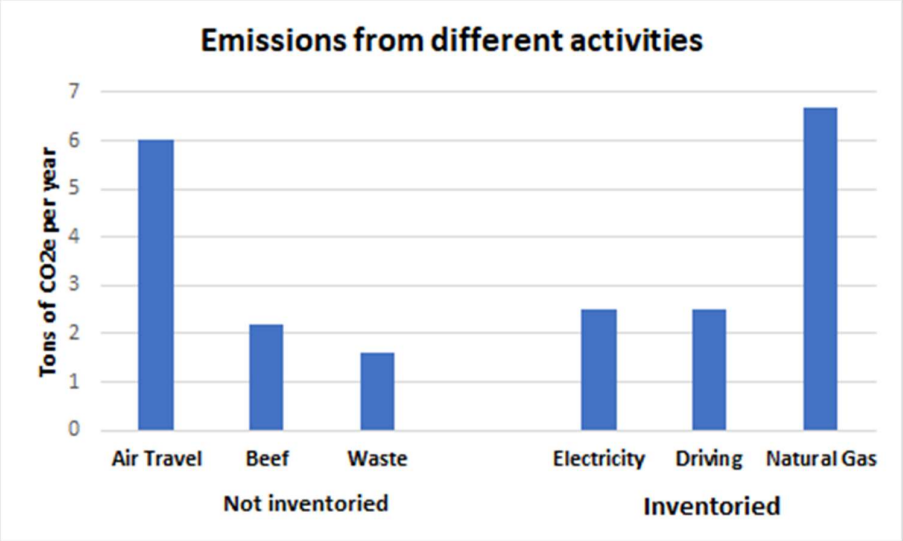


Figure 7: Emissions from activities that fall within the scope of the GHG inventory (right) and other emissions (left).

5. A Town-Wide Challenge

Belmont's Climate Action Plan is a town-wide commitment. Everybody has a part to play in making our Town of Homes into an example for a high quality, sustainable way of life. In proposing key strategies and targets to make progress quickly and effectively through strategic electrification, the Energy Committee has mapped out actions for a range of town boards, committees, and departments. For instance, Belmont Light will be a key community partner in this effort. These actions will succeed, however, only if a much broader range of people engage. Deep decarbonization will require us to change the way we heat our homes and transport ourselves from place to place. Town residents and businesses are going to need access to accurate and up-to-date information on the technologies, policies, and incentives available to accelerate that change. Town staff and volunteers can provide that information; however, members of the public need to do their research to figure out which technologies and programs will save them money and energy in the long term. And given that residents and businesses have a stake in the outcome, their feedback on this Roadmap can go a long way toward ensuring success in both its development and its implementation.

Broad public engagement is also critical to achieving emissions reductions beyond those from strategic electrification. As mentioned previously, many sources of emissions fall outside the scope of this Roadmap. Yet, that doesn't mean they're not an important part of the solution. Various committees and boards may have sway over whether or not Belmont has a healthy population of trees that will reduce both summer cooling costs and the urban heat island effect--and contribute to healthier air as side benefit. The committee on waste management may have ideas for how to achieve the "Reduce" part of "Reduce, Reuse, and Recycle" which would have a far bigger impact on emissions than recycling and composting alone. And, perhaps most importantly, members of the public can use their purchasing power to demand more sustainable products and services, with less packaging and more efficiency.

6. Continuous Evaluation and Progress

The work won't end once Belmont adopts the Roadmap. To succeed in the long run, Belmont will need continuous evaluation and progress. This will include, but not be limited to:

- Quarterly reports to the Board of Selectmen, which will be posted on the website
- Continued inventory updates every year, to be posted on the website
- Annual review by the Energy Committee of any necessary adjustments, to be posted on the website

The quarterly reports will show Belmont's progress on the interim targets detailed here, in addition to describing other accomplishments or upcoming opportunities related to emissions reductions. The annual review will account for any technology improvements, new policy tools, or state or federal initiatives that arise over the course of the previous year.

APPENDIX A: Cumulative emissions

The goal set in Belmont's Climate Action Plan is to achieve an 80% reduction of greenhouse gas emissions by 2050. The actions proposed in this roadmap would allow us to achieve this goal.

It matters, however, what path we take to get there. CO2 stays in the atmosphere for centuries. Because of this, what really matters for the climate is our **cumulative** emissions: how much total CO2 we emit this year and next year and the subsequent year and so on, all added together. Electrification and a shift to carbon-free electricity work together synergistically to reduce cumulative carbon emissions; the speed at which both are undertaken determines how much climate damage we will cause in total.

As an example, consider a scenario where we transition to carbon-free electricity at a slower rate than proposed, such that we steadily increase the fraction of carbon-free electricity used in future years but only reach 80% carbon-free electricity by 2050 (Figure 8B). While we could still (just) manage to achieve 80% reduction of overall emissions by 2050 under such a scenario, the cumulative CO2 emissions that would result between now and 2050 would be over 25% higher than with decarbonization of our electricity by 2022, due to ongoing emissions associated with our growing electricity use (shown in blue in A and B).

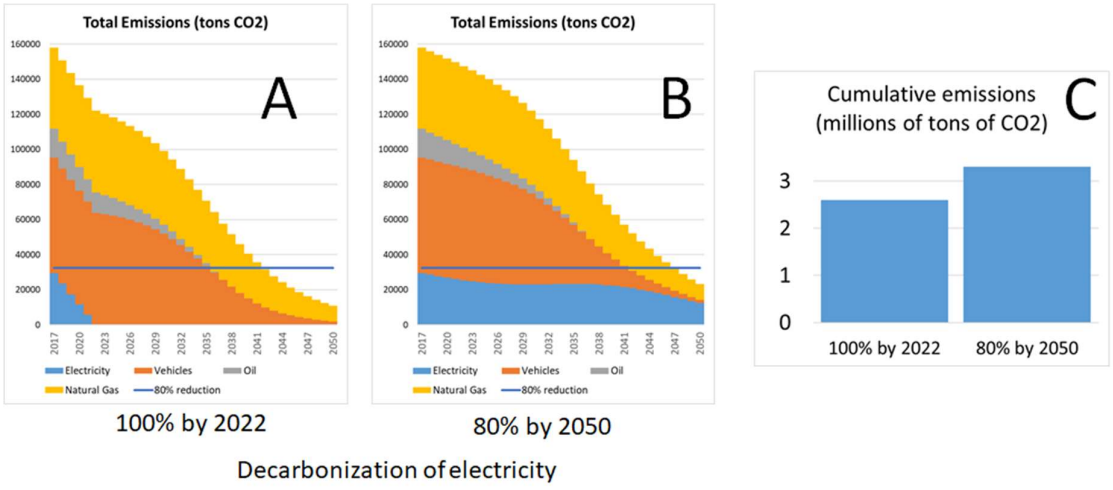


Figure 8. Comparison of emissions trajectories with different rates of decarbonization. A: with 100% carbon-free electricity by 2022. B: with 80% carbon-free electricity by 2050. C: Cumulative emissions from 2017-2050 under the two scenarios.

To minimize cumulative emissions, we need to move as quickly as possible to both electrify transportation and heating and make our electricity supply carbon-free.

The graphs in Figure 9 further explore how delays in the timelines of either electrification or of the decarbonization of our electricity supply lead to increased cumulative emissions between now and 2050. It should also be noted that the higher the level of remaining emissions in 2050, the higher emissions will be in subsequent years, so that cumulative emissions will continue to grow even beyond 2050.

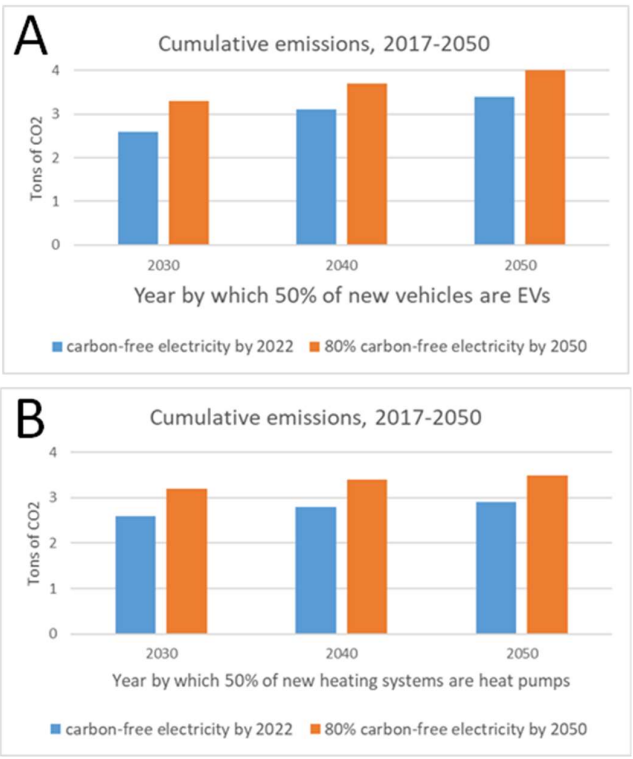


Figure 9. Cumulative emissions 2017-2050. Cumulative emissions are shown as a function of different rates of adoption of EVs (A) or heat pumps (B).

In A, the year for 50% of new sales of heating systems being heat pumps is kept constant as 2032 and in B, the year for 50% of new sales of vehicles being electric is kept constant as 2030. Two different scenarios are shown for decarbonization of electricity supply: 100% carbon-free by 2022 (blue bars) or 80% carbon-free by 2050 (red bars).

APPENDIX B: Modeling

The roadmap for electrification and decarbonization of electricity, and its impacts on carbon emissions, were modeled in an Excel spreadsheet that is available for download at:

https://www.dropbox.com/s/q0r0qf09vo2r9lc/Belmont%20Climate%20Roadmap%20public.xlsx?dl=0

Details of the modeling approach and assumptions made in the modeling are outlined in the spreadsheet under the tab labeled ASSUMPTIONS. Alternative scenarios and their effects on emissions can be explored by changing highlighted variables in the MASTER tab.