MARCH 9, 2020 WARRANT ARTICLE HEARING REFERENCE MATERIALS

ARTICLE 13

NOV. 2019 BROOKLINE SPECIAL TOWN MEETING
MATERIALS RE: ART. 21: "ON-SITE FOSSIL FUEL INFRASTRUCTURE"

ARTICLE 21

TWENTY-FIRST ARTICLE

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To see if the town will amend the General By-Laws by adopting a new article 8.39 entitled "Prohibition on New Fossil Fuel Infrastructure in Major Construction" as set forth below.

8.39.1 Purpose

This By-Law is adopted by the Town of Brookline, under its home rule powers and its police powers under Massachusetts General Laws, Chapter 40, Sections 21 (clauses 1, 18) and 21D, and Chapter 43B, Section 13, to protect the health, safety and welfare of the inhabitants of the town from fuel leaks and explosions and from air pollution, including that which is causing climate change and thereby threatens the Town and its inhabitants.

8.39.2 Definitions

"On-Site Fossil Fuel Infrastructure" is defined as fuel gas or fuel oil piping that is in a building, in connection with a building, or otherwise within the property lines of premises, extending from a supply tank or from the point of delivery behind a gas meter.

"New Building" is defined as a new building or new accessory building (a building devoted exclusively to a use accessory to the principal use of the lot) that is associated with a valid building permit application on or after the effective date of this article.

"Significant Rehabilitation" is defined as a renovation in which the work area, not including any added space, is more than 50% of the building floor area prior to the project, and that is associated with a valid building permit application on or after the effective date of this article.

8.39.3 Applicability

A. The requirements of this article shall apply to all permit applications for New Buildings and Significant Rehabilitations proposed to be located in whole or in part within the Town.

[1] Point of contact

B. The requirements of this article shall not apply to the use of portable propane appliances for outdoor cooking and heating, or to fuel pipes whose exclusive purpose is to fuel backup electrical generators.

C. The requirements of this article shall not apply to utility service pipe connecting the grid to a meter, or to a gas meter itself.

D. The requirements of this article shall not apply to any building being constructed subject to a Waldo-Durgin Overlay District Special Permit, as described in Section 5.06.4.k of the Zoning By-Law.

8.39.4 Effective Date and Enforcement

Effective June 1, 2020, no permits shall be issued by the Town for the construction of New Buildings or Significant Rehabilitations that include the installation of On-Site Fossil Fuel Infrastructure, except as otherwise provided in section 8.39.3.

8.39.5 - Severability

Each provision of this by-law shall be construed as separate to the extent that if any section, sentence, clause or phrase is held to be invalid for any reason, the remainder of the by-law shall continue in full force and effect.

Or act on anything relative thereto.

PETITIONER'S ARTICLE DESCRIPTION

Summary

This by-law will prohibit installation of fossil fuel piping in new buildings and in major renovation of existing buildings. Consequently, this policy will require heat, hot water, and appliances that are installed during new construction and gut renovation to be all-electric. For situations in which electric is not practical or cost effective, this by-law provides for exemptions, including for fuel piping for backup generators. An exception is also included for the Waldo-Durgin development, because it is the only major commercial project requiring a zoning change that has not yet pulled a building permit.

Rationale

We are facing a global climate crisis. This climate crisis directly affects Brookline residents and businesses. Massachusetts is one of the fastest-warming states in the country[2]. We have seen a rapid increase in extreme heat events that threaten the health of our children, our

[2] https://www.washingtonpost.com/graphics/2019/national/climate-environment/climate-change-america/

seniors, and those who need to work outside, not to mention our fragile ecosystem, our plants and wildlife. Rising seas and increased flooding threaten Boston and coastal communities[3]. Public health risks include an increase in heat-related illnesses and deaths, as well as outbreaks of insect-borne and waterborne diseases[4]. As natural ecosystems change or collapse, Massachusetts farmers, fishermen, and residents will suffer[5].

In its Climate Action Plan, Brookline has committed to reducing its carbon emissions to zero by 2050[6]. Every new building constructed with fossil fuel infrastructure makes this goal harder to achieve, by lighting a new fire that will burn, on and off, for thirty years or more. To meet our climate goal, each of these fires will need to be put out through the retrofitting of buildings, which account for 60-70% of our Town emissions[7]. It is unfair to the next generation to continue to install infrastructure that we already know will need to be replaced in a very short time.

Worsening gas leaks in underground pipes constitute their own significant dangers. Recent gas explosions in the Merrimack Valley[8], which killed one person and injured many more, and non-injurious explosions in Brookline[9], have put citizens at risk. 25% of the natural gas pipelines in Massachusetts are leak-prone and need repair and replacement[10]. Gas utilities, including in Brookline, are not adequately maintaining natural gas infrastructure by fixing unsafe leaks. Gas leaks have also killed trees in many places in Brookline.

In addition, the burning of fossil fuels inside buildings produces harmful indoor emissions[11] that emit nitrogen dioxide (NO_2), carbon monoxide (CO), and formaldehyde (HCHO),

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[3] https://ss2.climatecentral.org/#13/42.3232/-71.1423?show=satellite&projections=0-K14_RCP85-SLR&level=5&unit=feet&pois=hide

[4] https://www.annualreviews.org/doi/full/10.1146/annurev.publhealth.21.1.271

[5] https://www.mass.gov/service-details/climate-change-in-massachusetts-and-its-impacts and https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-ma.pdf and https://www.massaudubon.org/our-conservation-work/climate-change/effects-of-climate-change

[6] https://www.nature.com/articles/s41586-019-1364-3

[7] https://www.brooklinema.gov/ArchiveCenter/ViewFile/Item/628 (see footnote on sidebar)

[8] https://en.wikipedia.org/wiki/Merrimack_Valley_gas_explosions

[9] https://boston.cbslocal.com/2019/05/26/brookline-hammond-street-closed-manhole-fire-explosions/, https://patch.com/massachusetts/brookline/manhole-explosion-coolidge-corner-shuts-down-area, https://www.youtube.com/watch?v=Rbc11T8Vynw .

[10] https://eeaonline.eea.state.ma.us/DPU/Fileroom/dockets/bynumber (search by number for 18-GLR-01)

[11] Additional footnotes for statement on indoor emissions from:
https://healthyindoors.com/2018/07/cooking-indoor-air-pollution-emissions-natural-gas-stoves/
1. Klug VL, et al. Cooking Appliance Use in California Homes—Data Collected from a Web-based Survey. LBNL-5028E. Berkeley, CA:Lawrence Berkeley National Laboratory (August 2011). Available: http://homes.lbl.gov/sites/all/files/lbnl-5028e-cooking-appliance.pdf [accessed 5 December 2013].
2. Jarvis D, et al. The association of respiratory symptoms and lung function with the use of gas for cooking. Eur Respir J 11(3):651–658 (1998); http://www.ncbi.nlm.nih.gov/pubmed/9596117.
3. Jarvis D, et al. Association of respiratory symptoms and lung function in young adults with use of domestic gas appliances. Lancet 347(8999):426–431 (1996); http://dx.doi.org/10.1016/S0140-6736(96)90009-4.
4. EPA. Formaldehyde: Hazard Summary [website]. Washington, DC:U.S. Environmental Protection Agency (updated 18 October 2013) Available: http://www.epa.gov/ttnatw01/hlthef/formalde.html[accessed 5 December 2013].

each of which can cause various respiratory and other health ailments[12,13]. Cooking with gas has been linked to asthma and other adverse health effects, with children and low-income households particularly affected[14,15]. Nitrogen dioxide from gas stoves is linked to increased asthma rates among low-income preschoolers, and gas stoves are especially dangerous in smaller apartments with poor ventilation[16] and when they are used for supplemental heat. If the Clean Air Act applied inside homes, the air quality produced by cooking with gas would be illegal[17].

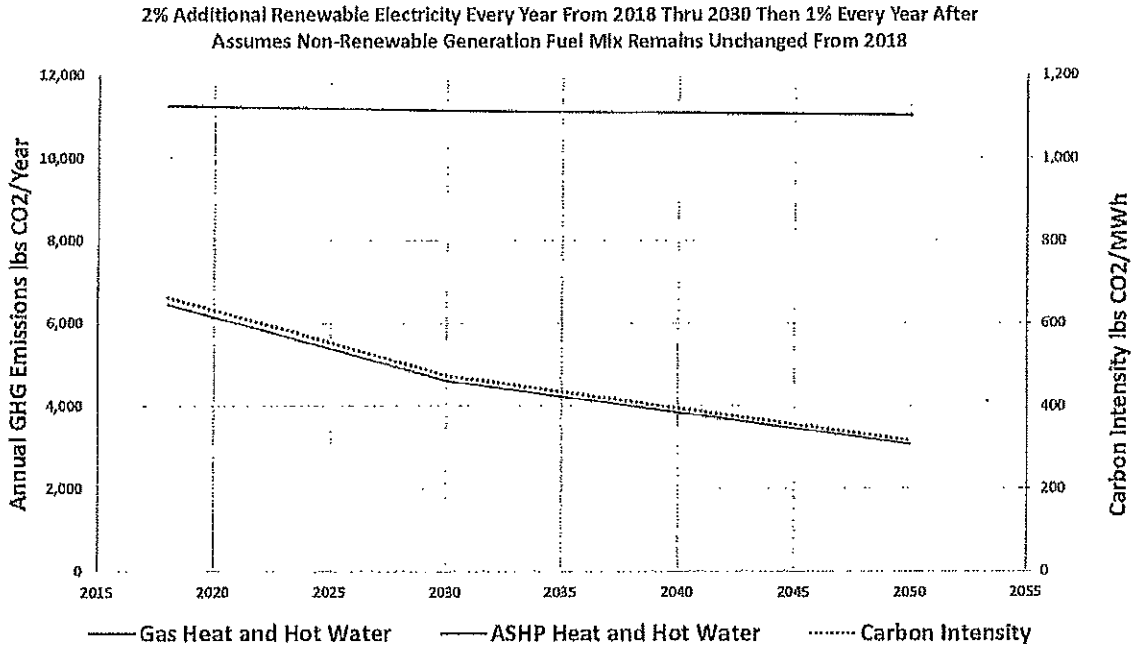

Figure 1: Comparing the Greenhouse Gas Emissions of an All-Electric House With Air Source Heat Pumps to a House With Natural Gas Heat and Hot Water

All-electric buildings are healthier and can operate immediately with zero emissions through the purchase of 100% renewable electricity with programs like Brookline Green Electricity[18]. Even buildings using the default New England electrical grid mix become greener every year as the electrical grid incorporates more and more renewable electricity

[12] https://www.nytimes.com/2019/05/01/opinion/climate-change-gas-electricity.html

[13] https://www.nytimes.com/2019/05/01/opinion/climate-change-gas-electricity.html

[14] https://www.sciencedaily.com/releases/2014/09/140929180523.htm and https://www.ncbi.nlm.nih.gov/pubmed/22082993 and https://scopeblog.stanford.edu/2018/03/06/use-your-range-hood-for-a-healthier-home-advises-indoor-air-quality-researcher/ and http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.277.9376&rep=rep1&type=pdf

[15] https://www.nytimes.com/2019/05/01/opinion/climate-change-gas-electricity.html

[16] http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.277.9376&rep=rep1&type=pdf

[17] https://well.blogs.nytimes.com/2013/07/22/the-kitchen-as-a-pollution-hazard/ and http://rebuildgreenexpo.com/wp-content/uploads/2019/06/ElectricMFGuide.pdf

[18] https://www.brooklinema.gov/1340/Brookline-Green-Electricity

generation, with a state-mandated minimum 60% renewable energy by 2050[19,20]. Figure 1 compares projected carbon emissions for a single family home built in Massachusetts using air-source heat pumps to provide electric heat and hot water with a similar home that uses gas heat and gas hot water. This projection assumes the home uses the default provider of electricity, which will become more renewable overtime. An all-electric home that elects to use 100 percent renewable electricity will have no carbon emissions from heat and hot water.

All-electric construction is practical and feasible now. Numerous all-electric buildings have been built recently in Massachusetts (Appendix D), demonstrating the feasibility and practicality of all-electric construction. Assuming that 0.5% of the building stock in Brookline is rebuilt or significantly renovated per year, this by-law would decarbonize 15% of our buildings by 2050. Decarbonizing in this manner, during new construction or major renovations is by far the most cost-effective way to decarbonize.

Practicality of all-electric buildings

All-electric construction is, in most cases, highly practical and essentially cost neutral. For example, one model commissioned for MassSave estimates a $754 construction cost premium for a 2,500 sq ft all-electric single family home[21], compared to the same home fitted with the most efficient gas heat and hot water systems and electric central air conditioning[22]. This premium is less than a 0.1% increase in cost for a typical new home like this in Brookline[23].

A relevant cost operations comparison comes from the same MassSave model cited above. Under this model, operation of a brand-new all-electric home in Massachusetts would be slightly more expensive than that of a brand-new gas home (by $41 per month). However, this $41 per month cost premium must be put into context. First, it is less than 1% of expected monthly costs on a newly built 2,500 sq ft Brookline home, including utilities, mortgage, and real estate tax payments. Second, if an electric ground source heat pump were used instead of an air source heat pump, the all-electric home would actually be less expensive to operate than the gas home. Third, when a new all electric building is compared with an existing building, the new all-electric one will be significantly less expensive to operate than gas, due to the far better air sealing and insulation required in new buildings.

Notably, building operation costs vary widely depending on building type, whether a building is new or retrofitted, whether a ground source or air source heat pump is used, whether solar is installed, the extent of air sealing and insulation, and other variables. To cite one example, buildings that are air sealed and insulated to Passive House standards can use less than 90% of the energy of buildings built to the minimal air sealing and insulation standards in the Massachusetts building code.

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[19] https://www.greenribboncommission.org/wp-content/uploads/2019/01/Carbon-Free-Boston-Report-web.pdf

[20] blog.greenenergyconsumers.org/blog/rps-res-in-plain-english

[21] built to the Massachusetts stretch energy code (a requirement in Brookline for new construction).

[22] http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_17-14_MiniSplitCost_27NOV2018_Final.pdf

[23] Assumes $1,000,000 purchase price.

Space heating and cooling

Heat pumps are air conditioners that can operate in reverse. Even in cold weather, they extract heat from outside air and move it into the building. Because they move heat rather than generating it, they are very efficient. Dramatic improvements in heat pump technology and building envelope technology now make it practical and cost-effective to heat new buildings with electricity in our climate[24]. (Electric heat pump heating should not be confused with electric resistance heat, which is inefficient and expensive[25].)

Buildings are becoming better insulated and more tightly sealed every year. As this happens, less and less heating and cooling is needed, and the cost of the HVAC systems decreases. Because more and more buildings are being built with air conditioning, heat pumps save money in two ways. First, only a single system needs to be installed rather than separate air conditioning and heating systems. Second, heat pumps are more efficient than old-fashioned air conditioning and save on electricity costs.

Cooking -- additional benefits of modern electric induction cooktops

Induction cooking has additional benefits beyond improved indoor air quality, health, and emissions reductions. Induction cooking is safer, more precise, and faster than cooking with gas.[26] Local professional Chef Ming Tsai of Blue Ginger and Blue Dragon fame has been using induction cooking for 20 years[27]. Local chef Barbara Lynch has one in her professional home kitchen[28]. Induction cooking keeps the kitchen cooler -- a major advantage in commercial kitchens -- and it can be so finely regulated that it can be used to melt chocolate without a double-boiler.[29]

Hot water heating. An electric heat pump hot water heater can be purchased from local home improvement stores and costs about the same to buy and operate as a gas-fired hot water heater. Costs of gas, electric resistance, and electric heat pump hot water heaters are described in Appendix B.

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[24] http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_17-14_MiniSplitCost_27NOV2018_Final.pdf

[25] Most electric heat in existing Brookline buildings is baseboard resistance heat, in which heat is generated, not moved. Electric resistance heat costs about three times as much to operate as a modern heat pump. In the past, heat pumps in MA were typically installed with electric resistance backup for the very coldest days of the year. Due to continual improvement of heat pump technology, the cold climate heat pumps recommended for use in New England either no longer include resistance heating elements or only use it a few days each year.

[26] https://www.consumerreports.org/electric-induction-ranges/pros-and-cons-of-induction-cooktops-and-ranges/

[27] http://sponsored.bostonglobe.com/frigidaire/induction/

[28] https://www.nytimes.com/video/dining/100000004082419/in-the-kitchen-with-barbara-lynch.html?action=click&module=RelatedCoverage&pgtype=Article&region=Footer

[29] Induction cooking should not to be confused with the dramatically inferior but often very similar-looking electric resistance cooking.

Clothes dryers. Many buildings already use electric resistance dryers. An alternative option, less expensive to operate, is the heat pump electric dryer. Compared to gas or most electric resistance dryers, heat pump dryers have the advantage of not requiring any outside venting. Costs of gas, electric, and electric heat pump dryers are described in Appendix C.

Appendix A -- Frequently Asked Questions

Q: If Brookline bans new fossil fuel infrastructure in major construction, do I get to keep my gas stove?

A: Yes. You can even replace it with a new one. You just can't install a new one in a brand new building or as part of a gut renovation. By 2050, 15% of Brookline's buildings would lack gas infrastructure, so even at that point there would under this policy be a lot of choice.

Q: Does this bylaw apply if I want to build an addition to my house?

A: It applies only if the project also includes major renovations to the existing part of your house AND if the renovated portion exceeds 50% of the area of the original building.

Q: Will this measure be effective (even if adopted beyond Brookline), or will the consequence simply be that more fossil fuels will be consumed in electricity generation?

If the occupant of a new all-electric building chooses to buy 100% renewable electricity, that all-electric building will be carbon-free from the moment it begins to operate.

Assuming the occupant relies on the standard grid mix, a new all-electric building built today would have lower overall emissions than an otherwise identical building with gas heat and appliances in the first year of operation (see chart above). These emissions savings will increase each additional year, as the grid greens through an existing statewide legislative mandate that requires a minimum 60% carbon-free grid by 2050. This grid greening is likely to be accelerated further at the state level and through Brookline's Green Electricity program. Thus, the emissions savings are very large compared to a building that burned natural gas over the course of those 31 years.

Q: Is there a good alternative for gas cooking, particularly in commercial settings?

Induction cooking is amazing. Many chefs who've tried it don't ever want to go back to gas, particularly in commercial settings[30,31]. It's safer, faster, and easier to control. It keeps the kitchen much cooler. The entire Bradley wing of LAX is all-electric[32], and the 24

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[30] http://sponsored.bostonglobe.com/frigidaire/induction/

[31] Drifter's Wife in Portland ME is recommended for best new restaurant that focuses on natural wines. "The entire kitchen is two induction burners and an oven," Li said. "The food they're putting out is amazing, and the wine experience overall is fantastic."
https://www.boston.com/travel/travel/2017/04/22/this-new-england-city-is-a-favorite-food-destination-for-boston-chefs

[32] https://www.urwairports.com/lax/retailer-category/dine/

restaurants there have induction and electric cooking but no gas ovens, stoves, or other gas infrastructure.

Q: What happens if the electricity goes out ? Will we be able to have gas back-up generators? Do you have exemptions or waivers for certain facilities that would need back-up systems such as nursing homes or daycares?

In short this policy would not affect what happens when the power goes out, which is that most buildings would lose their heat. The reason is that today's boilers and furnaces typically require both the gas AND the electrical grid, because they have electronic ignition systems that lack battery backups. Therefore, most buildings in Brookline are already fully dependent on the electrical grid for their heat.

For the few buildings, including schools and nursing homes, that need or want backup heating, the proposed policy includes an exemption for fuel pipes for backup generators.

Q: In light of the heat wave and the power outages in NYC, if we go all electric what happens to the stress or overloading of the Grid? Will there be more power outages as a result?

Electrical demand is currently declining in New England due to solar panels on building roofs and gains in energy efficiency (e.g., LEDs). There are declines in both annual and peak demand, and these declines are expected to continue[33]. The proposed bylaw policy affects too few buildings, too slowly, to affect the electrical grid significantly. It is the job of the utilities and the grid operator ISO-NE to keep the electricity flowing, and they should be capable of it -- and held to it. Nonetheless, both the gas and electrical grids do fail sometimes, as we saw last winter with the explosions and fires caused by the Columbia Gas infrastructure failure in the Merrimack Valley.

Our electrical grid is currently adding a lot of renewable generation -- utility-scale wind and solar. This new building policy will affect such a small fraction of buildings on the grid (~1% turnover in any one year, even if adopted across the entire New England grid territory), that it should not have an appreciable impact on the power grid, which already has year-on-year variation exceeding 1%[34].

Peak consumption is already a significant challenge to manage. But right now peak consumption is a summer problem, when AC kicks in on hot days. In the winter the bigger problem is actually natural gas shortages, which should be slightly alleviated by this policy. Because winter heating and summer AC are the biggest consumers of electricity in buildings, the proposed all-electric requirement would not have a very large impact on summer peaks. (People already use electricity for AC.)

Q: If this by-law is challenged in court, will it pass muster?

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[33] https://www.iso-ne.com/about/key-stats/electricity-use/

[34] https://www.iso-ne.com/about/key-stats/electricity-use/

Like any ground-breaking law, this bylaw may be challenged. But its rationale has been carefully thought through, and it is based on several months of legal consultations and research. We consulted with 14 lawyers, including the Berkeley outside counsel and the head of the Massachusetts Attorney General's Municipal Law Unit. Brookline Town Counsel then also provided advice. We believe that it will withstand a challenge, but the only way to find out for sure is to pass it. A crucially important strategy in fighting the fossil fuel industry is to win in court in defending new legal approaches to decarbonization.

Q Will there be only a few contractors that can design build these systems? Will that drive cost up?

This is very simple technology and many HVAC contractors have significant experience installing ASHPs. Ground source heat pump systems (GSHPs, sometimes referred to as "geothermal systems") have also been installed all over Massachusetts and the country for several decades.

Q: What if this by-law triggered the need for a significant upgrade of the electrical service to an existing building? For example, a 50-unit building that has original wiring from the street to the building from the 1940's. What if the electrical upgrade costs $200,000?

If one were doing a significant rehab of such a building, one would be spending millions to tens-of-millions of dollars. The $200,000 must be considered in that context. This is precisely why the trigger is major rehabilitations and new construction.

Q: Renovations and expansions are the most problematic. Think of a situation where someone has previously installed efficient gas boilers, etc. and they are trying to add on to their house, but they want to just use the same infrastructure. Are we really telling them that half of their house can still be gas but they need all new equipment for the second half?

As currently written, the work area *in the original space* would have to be over 50% of the original structure to trigger the by-law in the context of an addition. Just an addition alone without major rehabilitation in the existing portions of the building would not trigger this by-law. The vast majority of additions, such as adding a porch or remodeling a kitchen, do not meet this threshold.

Even if the work area *in the original space* exceeded the 50% floor area threshold, it would still be permissible to keep the efficient gas boiler. In other words ducts or water/steam pipes could be extended from the existing boiler or furnace into the addition. However, in this instance, fuel piping could not be installed into the new addition.

Appendix B -- Comparing Hot Water Heater Options

Manufacturer	Model	Type	Description	Price	Annual Energy Cost
A O Smith	ATI 240H 101	Tankless	Gas: Condensing	$912	$280
Rinnai	(RU1601) REU-N2530FF-US	Tankless	Gas: Condensing	$1,460	$280
Rinnai	(RUR1991) REU-NP3237FF-US	Tankless	Gas: Condensing	$2,014	$280
Rinnai	REU-VC2025FFU-US	Tankless	Gas: Condensing	$687	$282
Westinghouse	WGR050**076	Tank	Gas: Condensing	$1,951	$290
Rheem	XE80T10HD50U1	Tank	Electric: ASHP	$1,700	$306
A O Smith	HPTU-50N	Tank	Electric: ASHP	$1,380	$346
A O Smith	HPTU-66N 120	Tank	Electric: ASHP	$1,679	$356
Rheem	XG50T12HE40U0	Tank	Gas: Non-Condensing	$689	$407
Rheem	XE50M09EL55U1	Tank	Electric: Resistance	$524	$796

Comparing the Price and Operating Cost of a Variety of Hot Water Options

New homes in Brookline typically have a water heater with an Energy Star rating from the US Department of Energy. High efficiency (condensing) gas hot water heaters are available as hot water tanks and on-demand (tankless) models. High efficiency air source heat pump (ASHP) hot water tanks are another option. This table compares various types of hot water heaters based on data from the US Department of Energy. The prices are from Home Depot or similar outlets. The energy costs are based on what Brookline customers would be charged by Eversource and National Grid

Appendix C -- Comparing Clothes Dryer Options

Make	Model	CEF				Drum Size, Cubic Feet	Annual Energy Use	Price
Miele	PDR980 HP	9.75	Electric	Heat Pump	Ventless	4.6	87 kWh/Yr	
Miele	TWB120 WP	6.37	Electric	Heat Pump	Ventless	4.1	133 kWh/Yr	
Miele	TWF160 WP	6.37	Electric	Heat Pump	Ventless	4.1	133 kWh/Yr	$1,499
Samsung	DV22N6855'H'	5.85	Electric	Heat Pump	Ventless	4.0	145 kWh/Yr	
Whirlpool	WHD560CH**	5.2	Electric	Hybrid Heat Pump	Ventless	7.4	460 kWh/Yr	$1,259
Whirlpool	WHD862CH**	5.2	Electric	Hybrid Heat Pump	Ventless	7.4	460 kWh/Yr	
Whirlpool	WGD6620H**	3.48	Gas		Vented	7.4	687 Equivalent kWh/Yr	$900
Whirlpool	WGD9500EW*	3.48	Gas		Vented	8.2	687 Equivalent kWh/Yr	
Bosch	WTG86401UC	2.73	Electric	Condensing	Ventless	4.0	311 kWh/Yr	$1,125
Bosch	WTG86402UC	2.73	Electric	Condensing	Ventless	4.0	311 kWh/Yr	
Haier	QFT15ES'N***	2.68	Electric	Condensing	Ventless	3.1	317 kWh/Yr	

Price Range is roughly $600 to $1,000 for Conventional Electric Dryers
Price range is roughly $700 to $1,200 for Conventional Gas Dryers

Comparing the Price and Efficiency of Clothes Dryers

Stores have recently added a new option for buyers of clothes dryers: heat pump clothes dryers. The prices above are from Home Depot or similar outlets. Heat pump clothes dryers cost about the same to buy, but they are more efficient than gas dryers, so at current gas and electricity pricing, both cost about the same to operate. In addition, they don't have to be vented to the outside so they can be good for use in apartments and condominiums. The efficiency rating, CEF, is used by the US Department of Energy to rate the performance of clothes dryers. The higher the CEF, the higher the efficiency.

Appendix D - Partial list of buildings in New England with electric systems

Residential (up to 3 family)

Building name	*Heating and Cooling*	*Hot water*	*Location*
All-electric house, rehabilitated in 2018	*ASHP*	*Electric*	*Fisher Hill, Brookline, MA*
David Green's house	*ASHP*	*Electric*	*Dover, MA*
Holland House, Passive, LEED Platinum	*ASHP*	*Electric*	*Vineyard Haven, MA*
Torcellini residence	*ASHP, GSHP*	*Electric*	*Eastford, CT*
South End Row home by ZED	*ASHP*	*Electric*	*Boston, MA*
Dartmouth Oceanfront House by ZED	*ASHP*	*Electric*	*Dartmouth, MA*
Wellfleet modern house by ZED	*ASHP*	*Electric*	*Wellfleet, MA*
Thoughtforms Net positive farmhouse by ZED	*ASHP*	*Electric*	*Lincoln, MA*
Mediterranean style green home by ZED	*ASHP*	*Electric*	*Newton, MA*
Marshview house by ZED	*ASHP*	*Electric*	*Chatham, MA*

ASHP = Air Source Heat Pump, an all-electric technology for cooling and heating a building that is similar to an air conditioner but can also function in reverse to provide heat.
GSHP = ground source heat pump, similar to an ASHP but is more efficient due to its use of the ground, rather than the air, for heat transfer to and from the building.

Office buildings

Building name	Heating and Cooling	Hot Water	Location
Walden Pond Visitor Center, LEED, Passive, 5,575 sf	ASHP	Electric	Concord, MA
Bennington Superior Courthouse, Net Zero ready	GSHP		Bennington, VT
Massachusetts Fish & Wildlife Headquarters, Net Zero	GSHP	Electric	Westborough, MA
The Studio for High-Performance Design and Construction, Passive	ASHP	Electric	Newton, MA
185 Dartmouth	Heat pumps		Boston, MA
Olympia Place	Heat pumps	Propane	Amherst MA

ASHP = Air Source Heat Pump, an all-electric technology for cooling and heating a building that is similar to an air conditioner but can also function in reverse to provide heat.
GSHP = ground source heat pump, similar to an ASHP but is more efficient due to its use of the ground, rather than the air, for heat transfer to and from the building.

Educational facilities (including universities and schools)

Building name	Heating and Cooling	Hot water	Location
King Open School (middle school, elementary school, administrative offices, public pool)	GSHP	Electric	Cambridge, MA
Lexington Children's Place, Net Zero	Heat pumps	Electric	Lexington, MA
Hastings School, Net Zero	GSHP	Electric	Lexington, MA
The Putney School Field House, New Zero, LEED Platinum	ASHP	Electric	Putney, VT
R.W. Kern Center, Hampshire College	ASHP	Electric	Amherst, MA
Smith College, Bechtel Environmental Classroom	ASHP	Electric	Whately, MA
Trustees of Reservations, Powisset Net Positive Barn (demo kitchen with induction stoves, administrative offices, educational learning space, root cellar)	ASHP		Dover, MA

ASHP = Air Source Heat Pump, an all-electric technology for cooling and heating a building that is similar to an air conditioner but can also function in reverse to provide heat.
GSHP = ground source heat pump, similar to an ASHP but is more efficient due to its use of the ground, rather than the air, for heat transfer to and from the building.

Housing projects (large-scale)[35]

Building name	Heating and Cooling	Hot water	Location
Auburn Court Lot C. 9	Heat pumps		Cambridge, MA
Concord Highlands *	VRF ASHP		Cambridge, MA
Bayside Anchor, Passive House *	Electric baseboard heating[36], electric		Portland, ME

[35] Some central hot water systems for very large buildings are serviced by gas or oil. Those are indicated with a blank space in the Hot Water column.
[36] While generally inefficient, resistance electric heating is highly affordable in Passive House buildings due to their extremely low heating load.

	ventilation		
Bristol Common, Lexington Gardens *	ASHP		Taunton, MA
Highland Woods *	ASHP		Williamstown, MA
Parsons Village *	Heat pumps		Easthampton, MA
Millbrook Apartments	Heat pumps		Somerville, MA
Hyatt Centric Hotel	Heat pumps		Boston, MA
Distillery North	Heat pumps		Boston, MA
One East Pleasant	Heat pumps		Amherst, MA
Kendrick Place	Heat pumps		Amherst, MA
Whittier Street Apartments *	Heat pumps		Boston, MA
Factory 63	Heat pumps		Boston, MA

* = Affordable housing
ASHP = Air Source Heat Pump, an all-electric technology for cooling and heating a building that is similar to an air conditioner but can also function in reverse to provide heat.
GSHP = ground source heat pump, similar to an ASHP but is more efficient due to its use of the ground, rather than the air, for heat transfer to and from the building.

COMMISSION FOR DIVERSITY, INCLUSION AND COMMUNITY RELATIONS REPORT AND RECOMMENDATION

The mission of the CDICR is to support a welcoming environment by encouraging cooperation, tolerance, and respect among and by all persons who come in contact with the Town of Brookline (i.e. visitors, residents, employers, employees etc.) by advancing, promoting and advocating for the human and civil rights of all through education, awareness, outreach and advocacy.

The CDICR reviewed the warrant article on 10/23/2019. By a vote of 8-0-0, the CDICR recommends FAVORABLE ACTION on Warrant Article 21.

DISCUSSION:
Warrant article 21 seeks to offer a new by-law which would impose a prohibition on the installation of fossil fuel piping for new construction and significant rehabs (those involving more than 50% of the building floor area), allowing for some exemptions and a waiver process for special considerations. The alarming climate crisis calls on our town to establish such regulations. Indeed, the long-term welfare of our planet demands that we build structures that decrease our dependence on fossil fuels. When we speak of the cost of adapting to the realities of a changing climate, we need to consider the future costs of failing to address the effects of this crisis on the future of the environment.

It is now practical to build all electric buildings that can use all green electricity, thereby lowering Brookline's emission of green house gases. This by-law change has received unanimous endorsement from both the BHA and the HAB, which are now negotiating the waiver process. Questions were raised about the possibility that such a by-law change would be a disincentive for building affordable housing. We were told that in reality, affordable housing has been leading the way in building green. In terms of older buildings, there are new options for energy retrofits and training programs for workers who can do the work. As an example, BHA has plans to replace electric baseboard heating with heat pumps.

Therefore, the commission voted FAVORABLE ACTION on the warrant article, by a vote of 8-0-0.

SELECT BOARD'S RECOMMENDATION

A report and recommendation on Article 21 will be included in the supplemental mailing.

ADVISORY COMMITTEE'S RECOMMENDATION

The Advisory Committee's report and recommendation on Article 21 will be included in the supplemental mailing.

XXX

ARTICLE 21

SELECT BOARD'S SUPPLEMENTAL RECOMMENDATION

Article 21 is a petitioned article asking the Town to create a new by-law that would prohibit the installation of fossil fuel infrastructure in new buildings and gut/significant rehabilitation projects in Brookline. For these types of construction projects, installing gas or oil piping would be prohibited. This will have the effect of preventing the installation of new major appliances (e.g., boilers, furnaces, clothes dryers) or other systems that require on-site combustion of fossil fuels (e.g., natural gas or oil) for these types of projects. Specific exemptions are outlined in the By-Law, and construction project can also seek a waiver from a to-be-created Sustainability Review Board.

Specific exemptions in the By-Law include exemptions for piping required to fuel backup electrical generators, cooking and related appliances, centralized hot water systems in buildings with floor areas of at least 10,000 square feet (provided that the Engineer of Record certifies that no commercially available electric hot water heater exists), any building being constructed subject to a Waldo-Durgin Overlay District Special Permit, research laboratories for scientific or medical research or to medical offices regulated by the Massachusetts Department of Public Health as a health care facility, among other exemptions.

The Sustainability Review Board will be a three or more member Town Board established and appointed by the Select Board with expertise in affordable housing; commercial development; high-performance sustainable design; architecture; mechanical, electrical, and plumbing engineering; or other technical areas as determined by the Select Board.

The effective date will be the later of (1) January 1, 2021, (2) 5 months after written approval is received from the Attorney General's Office, or (3) the date upon which the Sustainability Review Board and its procedures have been established.

Significant consensus has been built between various boards, committees, commissions, community stakeholders and co-petitioners during the vetting of this Article. The Board appreciates the efforts of the petitioners and the Advisory Committee to craft language that can be supported by a wide range of stakeholders.

The Select Board unanimously voted FAVORABLE ACTION on the motion offered by the Advisory Committee.

ADVISORY COMMITTEE'S SUPPLEMENTAL RECOMMENDATION

SUMMARY:
Article 21 is intended to be a major step towards achieving Brookline's goal of reducing its carbon emissions to zero by 2050. It would, with limited exemptions, prohibit the installation of new fossil fuel pipe infrastructure (natural gas, propane, fuel oil) in new construction and so called "Significant Rehabilitations".

The Advisory Committee recommends FAVORABLE ACTION on Article 21 in the form presented on November 5, 2019.

As of November 11, the petitioners were considering revisions to the article that have not been reviewed by the Advisory Committee. No recommendation should be inferred for any version submitted subsequent to the November 5, 2019 vote.

BACKGROUND:
Article 21 is sponsored by a team of petitioners which include architects, lawyers, members of various advocacy groups including Mothers Out Front and the Greenspace Alliance plus three members of the Select Board.

The proposal is intended to support the Brookline Climate Action Plan which states the Town's intention to reducing its greenhouse emissions to zero by 2050. One strategy is to begin requiring the complete electrification of new buildings and buildings undergoing significant renovations. While the short term greenhouse emissions effects of this strategy is dependent on the fuels used to generate electricity, it is Massachusetts state policy to increase the percentage of electricity generated from renewable sources over time. Additionally, Brookline sponsors a community aggregation program in which the default choice has a higher percentage of renewable sources than the Eversource default. Plus Town electric customers can opt up to the Brookline Green Option which has 100% renewable source. Lastly, individual electricity consumers can make additional renewable investments on their own using strategies such as installation of onsite solar panels or participation in community solar.

The bylaw would prohibit installation of new fossil fuel piping in new buildings and "significant rehabilitation" of existing buildings. The original proposal had limited exemptions for (1) portable appliances for outdoor cooking and heating (ie., propane barbeque grills), (2) backup electrical generators and (3) the Waldo Durgin project (since that was the subject of a separate negotiation with the Town.) The original proposed effective date was June 1, 2020, but that has been revised to the later of:

1. January 1, 2021
2. 5 months after the Attorney General approves the bylaw
3. The date upon which the SRB is appointed by the Select Board and after a public hearing publishes its procedures and decision criteria.

The proposal does not affect existing piping, boilers, stoves or water heaters. However, in a covered project, the bylaw as originally proposed would prohibit new piping to accommodate relocating any existing appliances. For example, in a covered "gut" renovation project (called a "Significant Rehabilitation" in the bylaw) that includes a kitchen renovation, the homeowner would not be able to install pipes to relocate a gas stove to the other side of the room or to even move it a few inches.

Under the version of Article 21 adopted by the Advisory Committee and accepted by the petitioners, proposal, residential cooking appliances such as ranges, ovens and stovetops would not be covered even in a "gut" renovation, thus allowing renovated kitchens to continue to have gas appliances, no matter where in the kitchen the homeowner wishes to place them.

The petitioners, the Planning and Community Development Department plus various Town Boards and commissions have sponsored or participated in a number of "community feedback" sessions in addition to the normal vetting hearings that take place for Town Meeting warrant articles. As a result of the feedback prior to the Planning and Regulation Subcommittee's public hearing, the petitioners added additional exemptions for (1) restaurant kitchens, (2) large central hot water systems (with an engineer's statement) and (3) added a waiver process where it would be otherwise impractical or financially infeasible to go with all electric systems.

Additionally, with input from the Building Commissioner, they have attempted to clarify the definition of significant rehabilitation to generally correspond to a "Level 3" renovation as defined in the Building Code for commercial buildings. Exemptions proposed by others which the petitioners did not accept were (1) an exemption for all cooking, (2) a broad exemption for commercial buildings; (3) including only single family homes, and (4) including only new construction.

DISCUSSION:
Electrification of our infrastructure is one strategy to reduce and eventually eliminate our reliance on fossil fuels. Currently, fossil fuels (mainly natural gas in New England) are used to generate a percentage of our electricity, which percentage will decrease over time as more renewable generating sources come on line. No one on the Advisory Committee took issue with the need to reduce our carbon emissions and the electrification strategy. This report will now focus on the details of the proposed bylaw and the practical aspects of the proposal.

When the bylaw was originally submitted, the petitioners listed two exclusions; outdoor cooking and heating appliances and the Waldo-Durgin project. Waldo-Durgin was excluded because it was the subject of a Memorandum of Understanding with the Town which specifically addressed how the approaches to energy efficiency are to be handled

including involving the Town's Sustainability Program Administrator during the design phase.

Note that the bylaw only applies to new construction and so called gut renovations. No one is required to replace any existing gas appliances. Even in a gut renovation, a gas appliance can be replaced; but no new piping can be installed unless there is an exemption. But, in order for this to work, we need to have a sense of reality as to what can be replaced by electric appliances.

Heating and Cooling

In New England, space heating consumes the most energy in buildings. In Brookline, the predominant fuel source is natural gas and fuel oil. Many factors contribute to the amount of energy consumed including the efficiency of the heating appliance (furnace, boiler, heat pump, etc.) and how well the building envelope is insulated and sealed. This bylaw only addresses the fuel source, which is only one piece of the equation.

Typically, we think of electric heat as utilizing baseboard resistance heaters, which are cheap to install but very expensive to operate. The preferred electric heat sources now are either ground source or air source heat pumps. Heat pumps can be used for both air conditioning in summer and heating in winter. In winter, the refrigerant absorbs heat from the air outside (or the ground) and uses it to warm the space. Ground source heat pumps use heat drawn from geothermal wells to facilitate heat transfer. Generally, heat pumps are extremely efficient to operate (however as the temperature drops, heat pumps become less efficient and there is a point where they stop working though with today's heat pump they will work to as low as -25F degrees. The Planning and Regulation Subcommittee heard testimony that the industry is moving towards heat pumps as the preferred space heating and cooling technology and it works well for most applications.

Given the variety of commercial building types and their uses, blanket claims of practicality and financial feasibility of the technology for all uses are difficult to substantiate. The Planning and Regulation Subcommittee heard testimony that at least laboratories and certain types of medical offices have higher air circulation and replacement requirements, which heat pumps may not always be able to handle. We also need to balance the Town's critical financial need to be competitive with other communities with respect to promoting development of buildings devoted to medicine and science with its overall goal of reducing greenhouse emissions. The Town is in a unique position to leverage its close proximity to one of the world's great medical/science complexes.

The Advisory Committee therefore proposed, and the petitioner accepted, an exemption for such uses given the difficulty of quantifying the requirements to a degree sufficient to write into a bylaw in the timeframe of this Town Meeting. The failure to have a lab/medical exemption could work to divert such development to other close-by communities.

Domestic Hot Water

For residential and smaller commercial uses, there are practical alternatives to a gas hot water heater. These include traditional resistance and the newer technology heat pump hot water heaters.

For large central hot water systems, there are currently no alternates to the traditional gas hot water heater. Many large buildings are moving away from central hot water to a distributed hot water system, (the water is heated just prior to the using fixture or for a floor or unit in a building.), For systems of this type, there are electric alternatives.

The proposed bylaw does not mandate moving away from a central hot water system, and it implicitly recognizes the lack of alternatives. However, if an alternative becomes available, there is an exemption in the proposal if the alternative is more than 150% of the capital or operating cost of a conventional gas water heater as certified by an engineer. While at first glance a 150% cost differential seems high, remember that the requirement is only in effect for new construction or a "significant rehabilitation," where hot water will be a very small fraction of the total project cost.

Cooking

Cooking is where residents have the most interaction with natural gas. The bylaw, as originally submitted would have prohibited new fossil fuel infrastructure for cooking appliances.

There are two electric alternatives to the traditional gas range and stove top; the standard resistance electric range and the induction electric stove top. While resistance stoves work, they deliver a different, less controllable cooking experience. Induction stoves deliver a controlled cooking experience similar to natural gas but require cookware to be made of a magnetic based material such as cast iron or magnetic stainless steel. Aluminum or copper cookware does not work.

The subcommittee received an email and heard testimony from Dr. Jeffrey Macklis, Professor of Stem Cell and Regenerative Biology, Harvard University, and Professor of Neurology [Neuroscience], Harvard Medical School. Dr. Macklis researched induction stoves when he was considering purchasing one.

> "In brief, I found that the EU regulations and analyses show that a single burner on is reasonably safe for an adult user if the pan is of "appropriate"-correct size (completely covering the burner) and is perfectly centered with precision, but that this safety disappears for a pregnant abdomen with fetal head (developing brain) closer than 1 foot away, or a small child whose head (developing brain) would get closer than 1 foot away from the front of a burner. The EU agencies all point out that pregnancy and small children position developing brains directly at the least safe position– adjacent to the cooktop and at its level. That is because the main risk is within a foot or so (30 cm) of a burner, and electromagnetic field strength from the induction cooktop is limited by EU/Swiss/now US recommendation to approximately 6 uT (microTesla). While essentially all modern residential cooktops meet this standard for a single burner on with an optimally sized pot/pan that is

perfectly centered, they fail under "real world" scenarios. Unfortunately exposure with a differently sized pot/pan or one that is not optimally centered is often found to be ~5X higher (>30 uT!) than the regulatory agencies use as their acceptable limit! This even exceeds adult "occupational limits" set by the agencies. If more than one burner is on (e.g. for a normal meal or worst at a Thanksgiving dinner), the leakage around centered or uncentered pans is additive, though some will be further away than others."

Dr. Jesse Gray, disagreed with Dr. Macklis's assertions as follows:

"The concern raised here is a hypothetical one, since induction cooktops have been in widespread global use for decades without any demonstrated adverse health effects. No health or consumer protection authorities have banned induction cooktops for health or any other reasons, and there isn't a single peer-reviewed epidemiological study implicating induction cooking in any negative health impact. The petitioners brought this proposed by-law forward for climate reasons, not health reasons. However, in considering health, the competing technologies must be weighed against each other, since all technology has risks, and people are going to cook with one technology or another. As it stands, there is more substantial evidence about the dangers of gas cooking than there is about induction cooking. Gas cooking kills about 8,000 people every year in the United States due to fire. There are also well-documented health impacts from combustion byproducts of gas cooking, including asthma, that should be weighed against any hypothetical health impacts of induction cooking. These impacts of gas cooking are supported by numerous peer-reviewed epidemiological studies, unlike the speculative induction concerns."

Given (1) the competing health arguments, (2) the strong feelings by some about gas as a cooking energy source and (3) the unintended effect of prohibiting even small relocations of gas appliances in some kitchen renovations, the Advisory Committee was not prepared to support a complete ban of gas cooking appliances in projects subject to the bylaw at this time, and the petitioner accepted a cooking appliance exemption that includes residential properties.

Unsafe or Dangerous Condition Exemption

As originally submitted, the bylaw would not have permitted the repair of unsafe or dangerous existing gas infrastructure. An exemption has been added and agreed to by the petitioners.

Waivers and Appeals

This is a new area with developing technology and an all-electric infrastructure may not be practical or financially feasible in all situations not explicitly exempted by the bylaw. The Advisory Committee proposal creates a waiver and appeal process for these situations.
The Planning and Regulation Subcommittee heard concerns from the Economic Development Advisory Board, with respect to commercial development, the Housing

Advisory Board with respect to affordable housing and the Brookline Housing Authority with respect to their properties. For affordable housing in particular, capital funds may be limited to make investing in systems with lower operating costs in the long run difficult.

For all these Boards, a robust and effective waiver and appeal process is an essential component in coming to support the bylaw. The proposal establishes a "Sustainability Review Board" (SRB) to hear and decide waivers and appeals. The bylaw specifies that members shall possess areas of expertise with regards to affordable housing, commercial development, high-performance sustainable design, architecture, and mechanical, electrical, and plumbing engineering plus other technical areas as determined by the Select Board. The bylaw sets a general standard of review but requires the SRB to adopt procedural requirements with regard to filing waivers and appeals and criteria to evaluate projects. And one of the prongs for the effective date of the bylaw is the establishment of SRB and adopting procedures and criteria of review.

Other Municipal Ordinances

The movement surrounding mandating fossil fuel free infrastructures by municipal ordinance is a new one with the first such ordinance being passed in Berkley, CA on July 16, 2019. To the best of our knowledge, in the United States, only three other municipalities, all located in California, have passed similar ordinances since then. Other municipalities are considering this kind of legislation. All enacted ordinances, to date, cover only new construction and have various exemptions. They are summarized in the chart below:

City	Ord. Name	Summary	Exemptions	Commercial Buildings?
Brookline, MA (Proposed)	Article 21	Bans new fossil fuel infrastructure in all new construction and "Significant Rehabilitation(s)."	1. All cooking appliances 2. Backup generators 3. Outdoor cooking and heating 4. Large central hot water heaters 5.Waldo Durgin 6. Labs and certain medical offices 7. Repair unsafe conditions 8. Waivers if "financially infeasible or impractical"	Yes
Berkley CA	Ordinance No. 7.672–N.S.	The Berkley ordinance prohibits natural gas in **new** buildings. The ordinance is being rolled out gradually as the California Energy Commission (CEC) models different types of all-electric buildings. Currently, the ordinance bans installation of natural gas lines in low-rise residential buildings. As the CEC completes its modeling, the ordinance will expand to include additional building types.	Exemptions possible when a developer can demonstrate that all-electric isn't "physically feasible". There is also a general "public interest exemption" for cases where gas might be in the public interest to install vs. electric.	Eventually

City	Ord. Name	Summary	Exemptions	Commercial Buildings?
San Luis Obispo, CA	Clean Energy Choice Program	The Clean Energy Choice Program "encourages" all-electric **new** buildings. "Unlike some cities that are banning natural gas entirely, the Clean Energy Choice Program will provide options to people who want to develop new buildings with natural gas. New projects wishing to use natural gas will be required to build more efficient and higher performing buildings and offset gas use by performing retrofits on existing buildings or by paying an in-lieu fee that will be used for the same purpose.	Commercial kitchens are exempt. Various exemptions for "public health and safety" (e.g. hospitals) and an exemption for manufacturing that requires gas (see page 39 of ordinance for full list). The Clean Energy Choice Program also includes a "Public Interest Exemption", which allows the permitting authority to exempt projects should unexpected or unintended effects of the program arise.	Yes
Windsor, CA	Ordinance Adopting All-Electric Reach Code	All-electric requirement for **new** single-family homes, detached accessory dwelling units, and multi-family buildings up to three stories (also referred to as "low-rise residential")		No
San Jose, CA	Building Reach Code for New Construction	The passed ordinance will ban natural gas in the construction of **new** accessory dwelling units, new single family homes and new low rise and multifamily buildings.		Yes

City	Ord. Name	Summary	Exemptions	Commercial Buildings?
Menlo Park, CA	Ordinance No. 1057	Heating systems in all new homes and buildings in the city must run on electricity, and all new commercial, office and industrial buildings, as well as high-rise residences, must rely entirely on electricity. Although new one- and two-story homes will be allowed to have natural gas stoves, they must be built "electric ready" with the proper wiring to enable all-electric operation in the future.	Life sciences buildings and public emergency operations centers (e.g. fire stations) need to apply for an exemption, but are eligible. For single family and three stories or less multifamily: Natural gas can still be used for stoves, fireplaces or other appliances if desired (but prewiring for electric appliances is required where natural gas appliances are used.). Nonresidential kitchens, such as for-profit restaurants and cafeterias, may appeal under certain conditions to an appointed body designated by the City Council if they want to use natural gas stoves. The advisory body's decision can be appealed to City Council.	Yes

What renovations should be covered in addition to new construction?

Other than the Brookline bylaw, all of the bylaws referenced in the chart above cover only new construction. With new construction, the entire project can be planned and designed to maximize energy conservation and take into account the design requirements of all electric systems. Renovations present a set of complications since an all electric system will need to be retrofitted into an existing building envelope which was, in all likelihood, designed around a fossil fuel infrastructure. This only begins to make sense if all the walls are open which would be the case in a so called "gut" renovation. The Advisory Committee worked with the Building Commissioner and other staff in coming up with a legal definition that is understandable, relatively easy to enforce and, hopefully, minimizes the

unintended consequence of creating a trigger where walls are not open to the degree necessary to perform a deep energy efficiency retrofit.

For buildings subject to the commercial building code (residential buildings with 3 or more families plus commercial buildings), there is already a well-defined trigger called a Level 3 renovation when triggered, requires a high degree of code compliance. Building professionals plus the Town Building Department are familiar with this trigger and it is easily computed. For those properties, it makes sense to incorporate a Level 3 renovation into the definition of "Significant Rehabilitation."

In the residential building code, there is no parallel concept to a Level 3 commercial renovation. Our intent is to use the existing definition of Gross Floor Ratio in the zoning bylaw as the denominator to compute the percentage to define a "Significant Rehabilitation." Since we do not want to have an inadvertent trigger, we are opting to set the trigger percentage to a very high 75%. As we gain experience with the bylaw and gather data on how it is working, the percentage trigger can be adjusted at a future Town Meeting, if appropriate.

Legal issues

In Massachusetts, municipal ordinances cannot supersede the state building code which covers plumbing and other aspects of the building envelope and components. This proposed bylaw is constructed in way that attempts not to supersede the code but it is breaking new ground. As such, according to Associate Town Counsel Jonathan Simpson, there is no history or case law that directly speaks to the legal analysis of whether this bylaw is preempted. However, Mr. Simpson has cautioned that there could be several statutes that may preempt what this bylaw is attempting to do. The Office of the Attorney General (OAG), which reviews bylaws passed at Town Meeting, will not issue preliminary opinions, so the only way to know for sure whether OAG will approve a By-Law such as this, is to pass it at Town Meeting and submit it for OAG review. Even if we receive a rejection from the OAG, we will have gained some clarity as to how to approach this issue in the future. Note that even if the Attorney General approves the bylaw, it would still be subject to challenge by other parties.

Effective Date

As noted above, sufficient lead time for homeowners and developers has been provided to adjust their plans to comply with this bylaw.

RECOMMENDATION:

By a vote of 21-4 with four abstentions, the Advisory Committee recommends FAVORABLE ACTION on Article 21 as follows:

Voted: That the Town amend the General By-Laws by adopting a new article 8.39 entitled "Prohibition on New Fossil Fuel Infrastructure in Major Construction" as set forth below.

8.39.1 Purpose
This By-Law is adopted by the Town of Brookline, under its home rule powers and its police powers under Massachusetts General Laws, Chapter 40, Sections 21 (clauses 1, 18) and 21D, and Chapter 43B, Section 13, to protect the health and welfare of the inhabitants of the town from air pollution, including that which is causing climate change and thereby threatens the Town and its inhabitants.

8.39.2 Definitions
"New Building" is defined as a new building or new accessory building (a building devoted exclusively to a use accessory to the principal use of the lot) that is associated with a valid building permit application on or after the Effective Date.
"On-Site Fossil Fuel Infrastructure" is defined as fuel gas or fuel oil piping that is in a building, in connection with a building, or otherwise within the property lines of premises, extending from a supply tank or from the point of delivery behind a gas meter (customer-side of gas meter).
"Significant Rehabilitation" is defined as a renovation project associated with a valid building permit application on or after the Effective Date of this article that:

(1) For existing structures regulated by the current edition of the Massachusetts State Building Code 780 CMR 51.00, Massachusetts Residential Code, includes the reconfiguration of space and/or building systems, in which the Work Area, not including any added space, is more than 75% of the Gross Floor Area as defined in the Brookline Zoning By-Law;
(2) For existing structures regulated by the current edition of the Massachusetts State Building Code 780 CMR 34, the Massachusetts State Basic/Commercial Code, includes the reconfiguration of space and/or building systems, in which the Work Area, not including any added space, is more than 50% of the building floor area prior to the project, as defined by the Massachusetts Building Code.

"Sustainability Review Board" (SRB) is defined as a Town Board established and appointed by the Select Board whose members shall, to the extent possible, possess areas of expertise with regards to affordable housing, commercial development, high-performance sustainable design, architecture, and mechanical, electrical, and plumbing engineering and other technical areas as determined by the Select Board. The SRB shall have at least three members with three year staggered terms. The mission charge of the SRB shall be set by the Select Board. The mission charge shall be broad enough to perform the requirements of Sections 8.39.5 and 8.39.6.
"Work Area" is defined as the portions of a building affected by renovations for the reconfiguration of space and/or building systems, as indicated in the drawings associated with a building permit application. Areas consisting of only repairs, refinishing, and/or incidental work are excluded from the Work Area.

8.39.3 Applicability

The requirements of this article shall apply to all permit applications for New Buildings and Significant Rehabilitations proposed to be located in whole or in part within the Town as follows.

A. The requirements of this article shall not apply to utility service piping connecting the grid to a meter, or to a gas meter itself.
B. The requirements of this article shall not apply to piping required to fuel backup electrical generators.

C. The requirements of this article shall not apply to piping required for cooking appliances and related appliances.

D. The requirements of this article shall not apply to the use of portable propane appliances for outdoor cooking and heating.

E. The requirements of this article shall not apply to the piping required to produce potable or domestic hot water from centralized hot water systems in buildings with floor areas of at least 10,000 square feet, provided that the Engineer of Record certifies that no commercially available electric hot water heater exists that could meet the required hot water demand for less than 150% of installation or operational costs, compared to a conventional fossil-fuel hot water system.

F. So long as new fossil fuel piping is not installed, the requirements of this article shall not apply to the extension or modification of heating systems via HVAC system modification, or modification of radiator, steam, or hot water piping.

G. The requirements of this article shall not apply to any building being constructed subject to a Waldo-Durgin Overlay District Special Permit, as described in Section 5.06.4.k of the Zoning By-Law.

H. The requirements of this article shall not apply to research laboratories for scientific or medical research or to medical offices regulated by the Massachusetts Department of Public Health as a health care facility.

I. The requirements of this Article shall not apply to repairs of any existing portions of a fuel piping system deemed unsafe or dangerous by the Plumbing and Gas Fitting Inspector.

8.39.4 Effective Date and Enforcement

Upon the Effective Date, no permits shall be issued by the Town for the construction of New Buildings or Significant Rehabilitations that include the installation of new On-Site Fossil Fuel Infrastructure, except as otherwise provided in Sections 8.39.3, 8.39.5, and 8.39.6. As used herein, "Effective Date" shall be the later of (1) January 1, 2021, (2) 5 months after written approval of Article 8.39 is received from the Attorney General's

Office, or (3) the date upon which the SRB has been appointed and, after a public hearing, has adopted procedural requirements with regard to filing waivers and appeals and criteria to evaluate projects under Sections 8.39.5 and 8.39.6.

8.39.5 Waivers
A waiver from Article 8.39 may be sought from the SRB on the grounds of financial infeasibility supported by a detailed cost comparison, inclusive of available rebates and credits, or impracticality of implementation. A waiver request may be made at any time and may be based upon submission of conceptual plans. The SRB shall apply its criteria to evaluate whether particular portions of a project are financially infeasible or impractical to implement under the requirements of Section 8.39 and shall issue waivers narrowly for those portions, where appropriate, rather than for an entire project. Particular consideration for waivers will be given to projects sponsored by the Brookline Housing Authority (BHA), given the BHA's limited sources of capital funds.

8.39.6 Appeals
An appeal may be sought from the SRB following a denial of a building permit on the grounds that Article 8.39 is not applicable to a project pursuant to Section 8.39.3. Any appeal shall be supported by detailed information documenting the basis of the appeal.

ARTICLE 21

PETITIONER'S SUPPLEMENTAL EXPLANATION

Summary

This by-law will prohibit installation of fossil fuel piping in new buildings and in major renovation of existing buildings. Consequently, this policy will require heat, hot water, and appliances that are installed during new construction and major renovations to be all-electric. This by-law is intended to facilitate a practical transition to fossil fuel free buildings, and it thus provides for some exemptions including for fuel piping for backup generators, for cooking, and for central domestic hot water systems in large buildings.

Rationale

We are facing a global climate crisis. This climate crisis directly affects Brookline residents and businesses. Massachusetts is one of the fastest-warming states in the country. We have seen a rapid increase in extreme heat events that threaten the health of our children, our seniors, and those who need to work outside, not to mention our fragile ecosystem's plants and wildlife. Rising seas and increased flooding threaten Boston and coastal communities. Public health risks include an increase in heat-related illnesses and deaths, as well as outbreaks of insect-borne and waterborne diseases. As natural ecosystems change or collapse, Massachusetts farmers, fishermen, and residents will suffer.

In its Climate Action Plan, and consistent with state direction in the Green Communities Act, Brookline has committed to reducing its carbon emissions to zero by 2050. More recently, the United Nations International Panel of Climate Change announced in 2018 that we must reduce our carbon emissions by 50% by the year 2030 in order to avoid the most catastrophic effects of climate change. Buildings account for 60-70% of Brookline's emissions. Every new building constructed with fossil fuel infrastructure makes our emissions goal harder to achieve by lighting a new fire that will burn, on and off, for thirty years or more. To meet our climate goal, each of these fires will need to be put out through the retrofitting of buildings. It is unfair to the next generation to continue to install infrastructure that we already know will need to be replaced in a very short time. This by-law is an essential step if we are to have any hope of reaching Brookline's climate goals of zero emissions by 2050.

Eliminating fossil fuel infrastructure during new construction or major renovations is by far the most cost-effective way to decarbonize. All-electric construction is practical and feasible now. Numerous all-electric buildings have been built recently in Massachusetts (see Appendix B), demonstrating the feasibility and practicality of all-electric construction. Assuming that 0.5% of the building stock in Brookline is rebuilt or significantly renovated per year, this by-law would decarbonize 15% of our buildings by 2050.

All-electric buildings can operate immediately with zero emissions by purchasing 100% renewable electricity via programs such as Brookline Green Electricity. Even electric buildings using the default New England electrical grid mix are greener now than gas buildings, and they become greener every year as the electrical grid incorporates more and more renewable electricity generation, with a state-mandated minimum of 60% renewable energy by 2050.

Figure 1: Comparing the Greenhouse Gas Emissions of an All-Electric House with Air Source Heat Pumps to a House with Natural Gas Heat and Hot Water

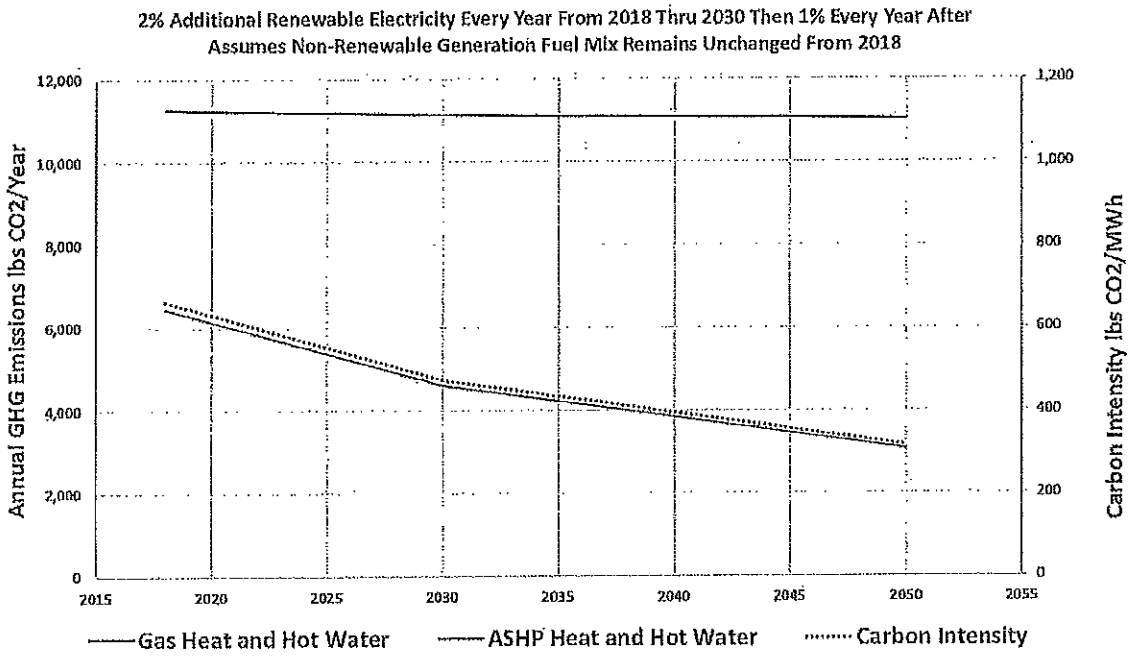

Figure 1 compares projected carbon emissions for a single-family home built in Massachusetts using air-source heat pumps to provide electric heat and hot water with a similar home that uses gas heat and gas hot water. This projection assumes the home uses the default electricity provider, which will include more renewable energy over time.

All-Electric Building Technology

Cost-effective and energy-efficient systems exist today for heating and cooling, domestic hot water, and other appliances for most buildings and applications.

Space heating and cooling. Heat pumps are air conditioners that can operate in reverse. Even in cold weather, they extract heat from outside air and move it into the building. Because heat pumps move heat rather than generating it, they are very efficient. Dramatic improvements in heat pump technology and building envelope technology now make it practical and cost-effective to heat new buildings with electricity in our climate.

Most new Brookline buildings have air conditioning. In buildings with both heating and air-conditioning, heat pumps save money in two ways. First, only a single system needs to be purchased and installed (rather than separate air conditioning and heating systems). Second, heat pumps are more efficient than air conditioners and save on electricity costs.

Hot water heating. An electric heat pump hot water heater can be purchased from local home improvement stores and costs about the same to buy and operate as a gas-fired hot water heater. The costs of gas, electric resistance, and electric heat pump hot water heaters are described in Appendix A.

Other Appliances. Clothes dryers, ovens, and cooktops are also available in all-electric options. Many buildings already use electric resistance dryers. An alternative option, less expensive to operate, is the heat pump electric dryer. Compared to gas or most electric resistance dryers, heat pump dryers have the advantage of not requiring any outside venting. In the kitchen, electric or induction cooktops and electric ovens provide alternatives to gas.

All-Electric Building Costs

Construction Costs: All-electric construction is, in most cases, highly practical and essentially cost neutral. For example, one model commissioned for MassSave estimates a $754 construction cost premium for a 2,500 sq. ft. all-electric single-family home, compared to the same home fitted with the most efficient gas heat and hot water systems and electric central air conditioning. This premium is less than a 0.1% increase in cost for a similar new home in Brookline, and it does not include available incentives that result in a net savings on construction of the all-electric home.

Operating Costs: Building operation costs vary widely depending on building type, whether a building is new or retrofitted, whether a ground source or air source heat pump is used, whether solar is installed, the extent of air sealing and insulation, and other variables. To cite one example, buildings that are air-sealed and insulated to Passive House standards can use less than 10% of the energy of many existing buildings, a difference in cost that is far greater than the differential cost of fuels.

A relevant operating cost comparison comes from the same MassSave model cited above. Under this model, operation of a brand-new all-electric home in Massachusetts would be slightly more expensive than that of a brand-new gas home (by $41 per month). However, this $41 per month cost premium must be put into context. First, this cost increase is less than 1% of expected monthly costs on a newly built 2,500 sq. ft. Brookline home, including utilities, mortgage, and real estate tax payments. Second, when new all-electric buildings are compared with older existing buildings, in which most of us in Brookline live, the new all-electric buildings are significantly less expensive to operate than the existing gas buildings, due to the far better air sealing and insulation required in new buildings.

Appendix A -- Frequently Asked Questions

Q: Will this measure be effective (even if adopted beyond Brookline), or will the consequence simply be that more fossil fuels will be consumed in electricity generation?

If the occupant of a new all-electric building chooses to buy 100% renewable electricity, that all-electric building will operate with low-carbon energy from the moment it begins to operate, which is a dramatic reduction in emissions.

Assuming the occupant relies on the standard grid mix, a new all-electric building built today would have lower overall emissions than an otherwise identical building with gas heat and appliances in the first year of operation (see Figure 1 above). These emissions savings will increase each additional year, as the grid greens through an existing statewide legislative mandate that requires a minimum 60% carbon-free grid by 2050. This grid greening is likely to be accelerated further at the state level and through Brookline's Green Electricity program. Thus, the emissions savings are very large compared to a building that burned natural gas over the course of those 31 years.

Q: In light of the heat wave and the power outages in NYC, if we go all electric what happens to the chance of overloading of the grid? Will there be more power outages as a result?

Electrical demand is currently declining in New England due to solar panels on building roofs and gains in energy efficiency. There are declines in both annual and peak demand, and these declines are expected to continue. In addition, our electrical grid is currently adding significant renewable generation -- utility-scale wind and solar.

The proposed bylaw policy affects too few buildings too slowly to affect the electrical grid significantly. This new building policy will affect such a small fraction of buildings on the grid (~1% turnover in any one year, even if adopted across the entire New England grid territory), that it should not have an appreciable impact on the power grid, which already has year-on-year variation exceeding 1%.

Peak consumption is already a significant challenge to manage. But right now peak consumption is a summer problem, when AC kicks in on hot days. Because winter heating and summer AC are the biggest consumers of electricity in buildings, the proposed all-electric requirement would not have a large impact on summer peaks, as people already use electricity for air conditioning.

Q: What happens if the electricity goes out? Will we be able to have gas back-up generators? Do you have exemptions or waivers for certain facilities that would need back-up systems such as nursing homes or daycares?

This policy would not affect what happens when the power goes out, which is that most buildings would lose their heat. The reason is that today's boilers and furnaces typically require both the gas AND the electrical grid, because they have electronic ignition systems that lack battery backups. Therefore, most buildings in Brookline are already fully dependent on the electrical grid for their heat. For the few buildings, including schools and nursing homes, that need or want backup heating, the proposed policy includes an exemption for fuel pipes for backup generators.

Q: If this by-law is challenged in court, will it pass muster?

Like any ground-breaking law, this by-law may be challenged. But its rationale has been carefully thought through, and it is based on several months of legal research. We consulted with many lawyers. We cannot guarantee that this by-law will withstand legal challenge, but we have made it as legally defensible as possible. The only way to find out if it will pass legal muster is to pass it.

Q Will there be only a few contractors that can design build these systems? Will that drive costs up?

Many HVAC contractors have significant experience installing air source heat pumps. Ground source heat pump systems (sometimes referred to as "geothermal systems") have also been installed state- and nation-wide for several decades.

Q: What if this by-law triggered the need for a significant upgrade of the electrical service to an existing building? For example, a 50-unit building that has original wiring from the street to the building from the 1940's. What if the electrical upgrade costs $200,000?

Major renovations to multi-unit buildings cost millions to tens-of-millions of dollars. The $200,000 electrical upgrade cost must be considered in that context. This is precisely why the proposed by-law trigger is major rehabilitations and new construction.

Q: Does WA21 apply if I want to build an addition to my house?

As currently written, the work area *in the original space* would have to be over 50-75% of the original structure to trigger the by-law in the context of an addition. Just an addition alone without major rehabilitation in the existing portions of the building would not trigger this by-law. The vast majority of additions, such as adding a porch or remodeling a kitchen, do not meet this threshold. Even if the work area *in the original space* exceeded the 50-75% floor area threshold, it would still be permissible to keep an oil or gas boiler. In other words, ducts or water/steam pipes could be extended from the existing boiler or furnace into the addition. However, in this instance, fuel piping could not be installed into the new addition.

Appendix A -- Comparing Hot Water Heater Options

Manufacturer	Model	Type	Description	Price	Annual Energy Cost
A O Smith	ATI 240H 101	Tankless	Gas: Condensing	$912	$280
Rinnai	(RU1601) REU-N2530FF-US	Tankless	Gas: Condensing	$1,460	$280
Rinnai	(RUR1991) REU-NP3237FF-US	Tankless	Gas: Condensing	$2,014	$280
Rinnai	REU-VC2025FFU-US	Tankless	Gas: Condensing	$687	$282
Westinghouse	WGR050**076	Tank	Gas: Condensing	$1,951	$290
Rheem	XE80T10HD50U1	Tank	Electric: ASHP	$1,700	$306
A O Smith	HPTU-50N	Tank	Electric: ASHP	$1,380	$346
A O Smith	HPTU-66N 120	Tank	Electric: ASHP	$1,679	$356
Rheem	XG50T12HE40U0	Tank	Gas: Non-Condensing	$689	$407
Rheem	XE50M09EL55U1	Tank	Electric: Resistance	$524	$796

Comparing the Price and Operating Cost of a Variety of Hot Water Options

This table compares various types of hot water heaters based on data from the US Department of Energy. The prices are from Home Depot or similar outlets. The energy costs are based on what Brookline customers would be charged by Eversource and National Grid.

Appendix B - Sample Buildings in New England with Electric Systems

Residential (up to 3 family)

Building name	Heating and Cooling	Hot water	Location
All-electric house, rehabilitated in 2018 by Byggmeister	ASHP	Electric	Fisher Hill, Brookline, MA
Holland House, Passive, LEED Platinum, Hutker Architects	ASHP	Electric	Vineyard Haven, MA
Torcellini residence, Paul Torcellini	ASHP, GSHP	Electric	Eastford, CT
South End Row home by Zero Energy Design	ASHP	Electric	Boston, MA
Dartmouth Oceanfront House by Zero Energy Design	ASHP	Electric	Dartmouth, MA
Wellfleet modern house by Zero Energy Design	ASHP	Electric	Wellfleet, MA
Thoughtforms Net positive farmhouse by Zero Energy Design	ASHP	Electric	Lincoln, MA
Mediterranean style green home by Zero Energy Design	ASHP	Electric	Newton, MA
Marshview house by Zero Energy Design	ASHP	Electric	Chatham, MA

ASHP = Air Source Heat Pump, an all-electric technology for cooling and heating a building that is similar to an air conditioner but can also function in reverse to provide heat.
GSHP = ground source heat pump, similar to an ASHP but is more efficient due to its use of the ground, rather than the air, for heat transfer to and from the building.

Office buildings

Building name	Heating and Cooling	Hot Water	Location

Walden Pond Visitor Center, LEED, Passive, Maryann Thompson Architects	ASHP	Electric	Concord, MA
Bennington Superior Courthouse, Net Zero ready, Maclay Architects	GSHP		Bennington, VT
Massachusetts Fish & Wildlife Headquarters, Net Zero, Ellen Watts, Architerra	GSHP	Electric	Westborough, MA
The Studio for High-Performance Design and Construction, Passive, Studio HPDC	ASHP	Electric	Newton, MA
185 Dartmouth, Bargmann Hendrie + Archtype	Heat pumps		Boston, MA
Olympia Place, DiMella Shaffer and Holst Architecture	Heat pumps	Propane	Amherst MA

ASHP = Air Source Heat Pump, an all-electric technology for cooling and heating a building that is similar to an air conditioner but can also function in reverse to provide heat.
GSHP = ground source heat pump, similar to an ASHP but is more efficient due to its use of the ground, rather than the air, for heat transfer to and from the building.

Educational facilities (including universities and schools)

Building name	Heating and Cooling	Hot water	Location
King Open School (middle school, elementary school, administrative offices, public pool), William Rawn Associates, Architects	GSHP	Electric	Cambridge, MA
Lexington Children's Place, Net Zero, DiNisco Design, Inc.	Heat pumps	Electric	Lexington, MA
Hastings School, Net Zero, DiNisco Design, Inc.	GSHP	Electric	Lexington, MA
The Putney School Field House, New Zero, LEED Platinum, Maclay Architects	ASHP	Electric	Putney, VT
R.W. Kern Center, Hampshire College, Bruner/Cott Architects	ASHP	Electric	Amherst, MA

Smith College, Bechtel Environmental Classroom, Coldham and Hartman Architects	ASHP	Electric	Whately, MA
Trustees of Reservations, Powisset Net Positive Barn (demo kitchen with induction stoves, administrative offices, educational learning space, root cellar), Zero Energy Design	ASHP		Dover, MA

ASHP = Air Source Heat Pump, an all-electric technology for cooling and heating a building that is similar to an air conditioner but can also function in reverse to provide heat.
GSHP = ground source heat pump, similar to an ASHP but is more efficient due to its use of the ground, rather than the air, for heat transfer to and from the building.

Housing projects (large-scale)

Building name	Heating and Cooling	Hot water	Location
Auburn Court Lot C. 9, Goody Clancy Architects	Heat pumps		Cambridge, MA
Concord Highlands, ICON Architecture	VRF ASHP		Cambridge, MA
Bayside Anchor, Passive House, Kaplan Thompson Architects ⋆	Electric baseboard heating, electric ventilation		Portland, ME
Bristol Common, Lexington Gardens, The Architectural Team ⋆	ASHP		Taunton, MA
Highland Woods, Dietz and Company Architects	ASHP		Williamstown, MA
Parsons Village, Dietz and Company Architects	Heat pumps		Easthampton, MA
Millbrook Apartments, Bargmann Hendrie + Archetype Inc.	Heat pumps		Somerville, MA
Hyatt Centric Hotel, Arrowstreet	Heat pumps		Boston, MA
Distillery North, ICON Architecture	Heat pumps		Boston, MA

One East Pleasant, Holst and DiMella Shaffer	Heat pumps		Amherst, MA
Kendrick Place, Holst and DiMella Shaffer	Heat pumps		Amherst, MA
Whittier Street Apartments, The Architectural Team	Heat pumps		Boston, MA
Factory 63, Gerding Edlen	Heat pumps		Boston, MA

⋆ = Affordable housing

ASHP = Air Source Heat Pump, an all-electric technology for cooling and heating a building that is similar to an air conditioner but can also function in reverse to provide heat.

GSHP = ground source heat pump, similar to an ASHP but is more efficient due to its use of the ground, rather than the air, for heat transfer to and from the building.

ARTICLE 24

MODEL RANKED CHOICE VOTING ORDINANCE

Model Statute

An Act to Elect Certain Offices by Ranked Choice Voting

SECTION 1: OFFICES ELECTED BY RANKED CHOICE VOTING

Contests for each of the following offices shall be conducted by ranked choice voting: governor, member of the state senate, member of the state house of representatives, member of the United States House of Representatives, and United States Senator.

SECTION 2: RANKED CHOICE VOTING BALLOT

(a) In any contest conducted by ranked choice voting with three or more qualified candidates, including qualified write-ins, the ballot shall allow voters to rank candidates in order of choice.
(b) If feasible, the ballot shall allow voters to rank as many choices as there are qualified candidates. In the event that the voting equipment cannot feasibly accommodate a number of rankings on the ballot equal to the number of qualified candidates, the ballot may limit the number of choices a voter may rank to the maximum number allowed by the equipment, provided the ballot must allow the voter to rank at least six choices.
(c) The ballot shall not interfere with a voter's ability to rank a write-in candidate.

SECTION 3: RANKED CHOICE VOTING TABULATION

(a) **SINGLE WINNER TABULATION.** - In any contest for exactly one office conducted by ranked choice voting, tabulation proceeds in rounds. Each round proceeds sequentially as follows:

1. Each ballot shall count as one vote for the highest-ranked continuing candidate on that ballot. If two or fewer continuing candidates remain, the candidate with the fewest votes is defeated, the candidate with the greatest number of votes is elected and tabulation is complete.
2. If more than two continuing candidates remain, the continuing candidate with the fewest votes is defeated, and a new round begins with subsection (a)(1).

(b) **MULTI WINNER TABULATION.** - In any contest for more than one office conducted by ranked choice voting, tabulation proceeds in rounds. If, in the initial tabulation, the number of continuing candidates is less than or equal to the number of offices to be elected, then all continuing candidates are elected and tabulation is complete. Otherwise, each round proceeds sequentially, until tabulation is complete, as follows:

1. Each ballot shall count, at its current transfer value, for the highest-ranked continuing candidate on that ballot. If the sum of the number of elected candidates and the number of continuing candidates is equal to the sum of one and the number of offices to be elected, then the candidate with the fewest votes is defeated, all other continuing candidates are elected, and tabulation is complete.
2. If at least one continuing candidate has more votes than the election threshold for the contest, then

each such candidate is elected. Each ballot counting for an elected candidate is assigned a new transfer value by multiplying the ballot's current transfer value by the surplus fraction for the elected candidate, rounded down to four decimal places and ignoring any remainder. Each candidate elected under this subsection is deemed to have a number of votes equal to the election threshold for the contest in all future rounds. A new round begins with subsection (b)(1).

3. If no candidate is elected under subsection (b)(2), then the continuing candidate with the fewest votes is defeated, and a new round begins with subsection (b)(1).

(c) **INACTIVE BALLOTS.** - In any round of tabulation in a contest conducted by ranked choice voting, a ballot that does not contain a highest-ranked continuing candidate shall not count for any candidate. Instead, it shall be counted as an overvote, abstention, or exhausted ballot.

(d) **BATCH ELIMINATION.** - In any contest conducted by ranked choice voting, the chief election official may modify the tabulation to include batch elimination. If the tabulation does include batch elimination, then any time the continuing candidate with the fewest votes would be defeated, each continuing candidate in the elimination batch shall be simultaneously defeated instead. A continuing candidate is in the elimination batch if the number of elected and continuing candidates with more votes than that candidate is greater than the number of offices to be elected, and it is mathematically impossible for that candidate to be elected for any of the following reasons:

1. The candidate has fewer votes than any other continuing candidate.
2. The candidate could never win because the candidate's current vote total plus all votes that could possibly be transferred to the candidate in future rounds would not be enough to equal or surpass the continuing candidate with the next higher current vote total.
3. The candidate has a lower current vote total than a continuing candidate who is described by (2).
4. The candidate could never win because the number of ballots with any highest-ranked continuing candidate, on which that candidate is ranked at any ranking order, is smaller than the following:
    a. For contests for exactly one office: the current vote total of the continuing candidate with the greatest number of votes.
    b. For contests for more than one office: the current vote total of any of the top "x" continuing candidates with the highest current vote totals, where "x" is the number of offices to be elected.

(e) **TIES.** - If two or more candidates are tied with the fewest votes, and tabulation cannot continue until the candidate with the fewest votes is defeated, then the candidate to be defeated shall be determined by lot. Election officials may resolve prospective ties between candidates prior to tabulation after all votes are cast.

(f) **DEFINITIONS.** - For the purposes of this section, the following terms have the following meanings:

1. "Abstention" means a ballot that does not contain a highest-ranked continuing candidate and either more than one ranking order contains the same candidate or one or more ranking orders did not contain any candidate.

2. "Continuing candidate" means any candidate that has not been defeated or elected.
3. "Election threshold" means the number of votes sufficient for a candidate to be elected in a multi winner contest. The election threshold is calculated by dividing the total number of votes counting for continuing candidates in the first round by the sum of one plus the number of offices to be filled, rounding up to four decimal places.
4. "Exhausted ballot" means a ballot that does not contain a highest-ranked continuing candidate and is not an abstention or an overvote.
5. "Highest-ranked continuing candidate" means the candidate assigned to the highest ranking order that is neither a skipped ranking nor follows two or more consecutive skipped rankings nor contains an elected or defeated candidate nor contains more than one candidate nor follows a ranking order that contains more than one candidate.
6. "Inactive ballots" are all ballots that do not contain a highest-ranked continuing candidate, including abstentions, overvotes, and exhausted ballots.
7. "Overvote" means a ballot that does not contain a highest-ranked continuing candidate because the highest ranking order that is neither a skipped ranking nor contains an elected or defeated candidate contains more than one candidate or follows a ranking order that contains more than one candidate.
8. "Ranking order" means the number available to be assigned by a voter to a candidate to express the voter's choice for that candidate. The number "1" is the highest ranking order, followed by "2" and then "3" and so on.
9. "Round" means an instance of the sequence of voting tabulation beginning with subsection (a)(1) of this section for single winner contests or (b)(1) of this section for multi winner contests.
10. "Skipped ranking" means a voter has left a ranking order unassigned but ranks a candidate at a subsequent ranking order.
11. "Surplus fraction" is a number equal to the quotient of the difference between an elected candidate's vote total and the election threshold, divided by the candidate's vote total, rounded down to four decimal places, ignoring any remainder.
12. "Transfer value" means the proportion of a vote that a ballot will contribute to its highest-ranked continuing candidate. Each ballot begins with a transfer value of 1. If a ballot contributes to the election of a candidate under subsection (b)(2), it receives a new transfer value.

SECTION 4: RULEMAKING AUTHORITY

The chief election official shall have the authority to make any changes to the ranked choice voting ballot and tabulation process necessary to preserve the secrecy of the ballot and ensure the integrity and smooth functioning of the election, provided that ranked choice voting shall still be used and the smallest number of changes made to achieve such purpose.