Cooling and Electrifying Affordable Housing: Related Climate Resilience and Mitigation Challenges

Presented to
The Energy Cohort

September 10th, 2020

Agenda

Overview of the Trends

- Temperature Increases/Extreme Heat
- Electrification

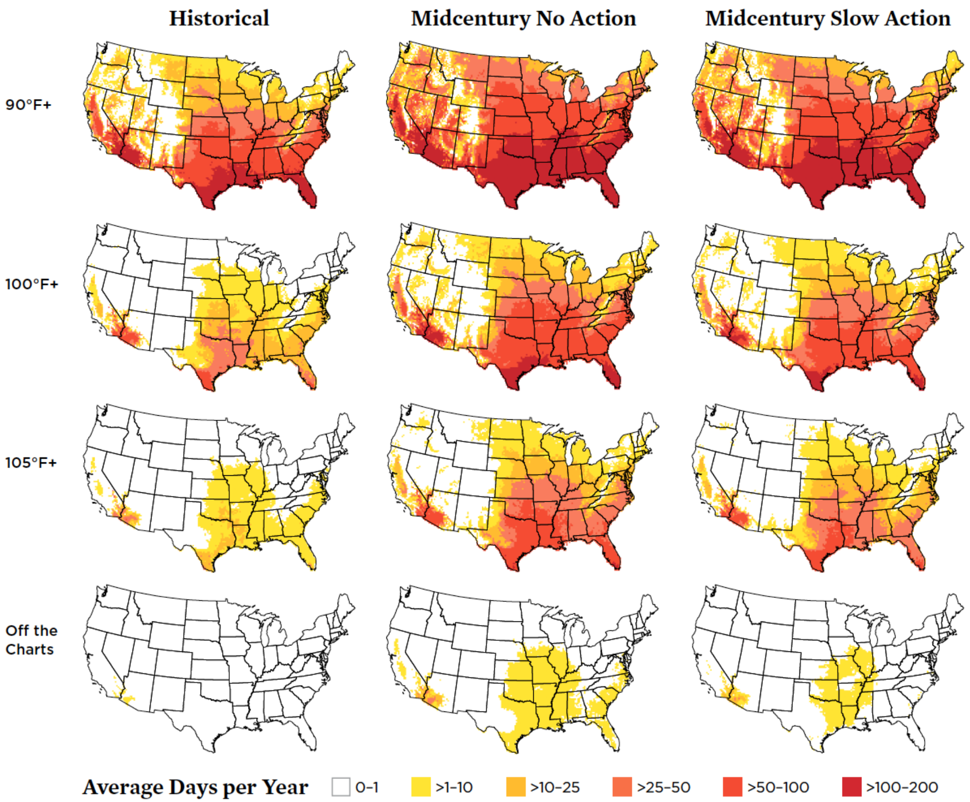
Strategies for Adding Cooling: Pros and Cons

- Window A/C
- A/C Sleeves
- PTHP
- Air Source Heat Pumps: Mini or Multi-Split
- Air Source Heat Pump: VRF
- Other Variations

“From a public health perspective, heat has been the largest single weather-related cause of death in the U.S. since the National Oceanic and Atmospheric Administration (NOAA) began reporting data in 1988. Fortunately, heat impacts on health are the most well understood, measurable, and potentially preventable impacts of climate change.”

- City of Cambridge Climate Change Vulnerability Report: Part I, 2015

FIGURE 5. Extreme Heat by Midcentury Becomes More Frequent and Widespread



By midcentury (2036–2065), regions of the United States with little to no extreme heat in an average year historically—such as the upper Midwest and New England—would begin to experience such heat on a regular basis. Heat conditions across the Southeast and Southern Great Plains regions are projected to become increasingly oppressive, with off-the-charts days happening an average of once or more annually.

City of Cambridge: Climate Change Vulnerability Assessment (2015)

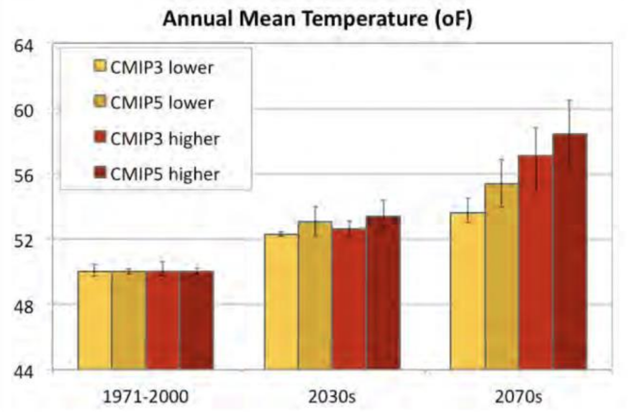


Figure 4. Historical and projected future annual mean temperature, based on the average of three long-term weather stations shown in Figure 3. Yellow bars show projected changes under lower scenarios and red bars, under higher. CMIP3 are the older generation of global climate models, and CMIP5 are the newer generation. The ranges on each bar show the projections from all the different models in each group (4 models in CMIP3 and 9 models in CMIP5).

“By 2030, annual days over 90F may triple….By 2070, Cambridge may experience nearly 3 months over 90F, compared to less then 2 weeks in present day”

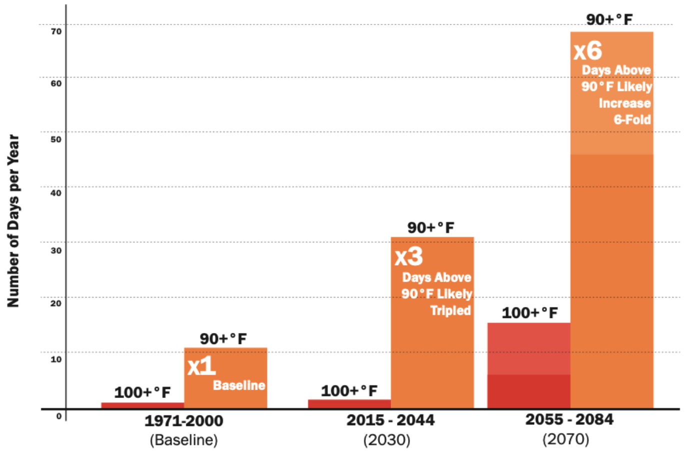


Fig. 15 **Number of days above 90ºF** (Source: Kleinfelder based on ATMOS research, November 2015)

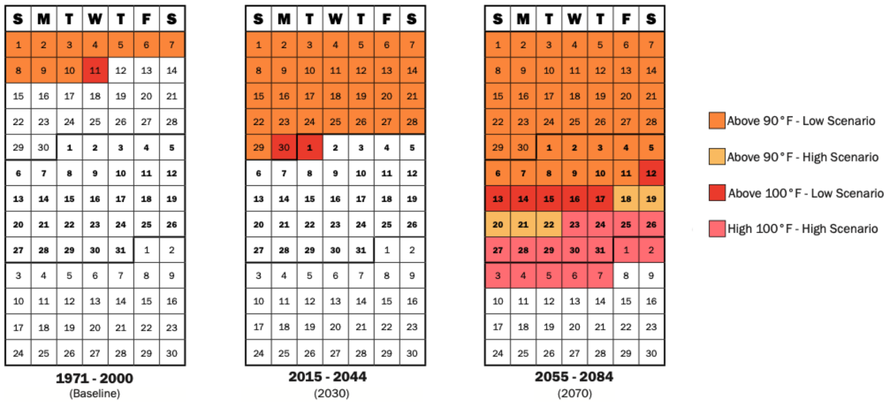


Fig. 16 **Relative increase in possible projected days above 90ºF and 100ºF over a 3-month period** (Source: Kleinfelder based on ATMOS research, November 2015)

“Heat Vulnerability and Inland flooding are more imminent concerns for Cambridge than sea level rise”

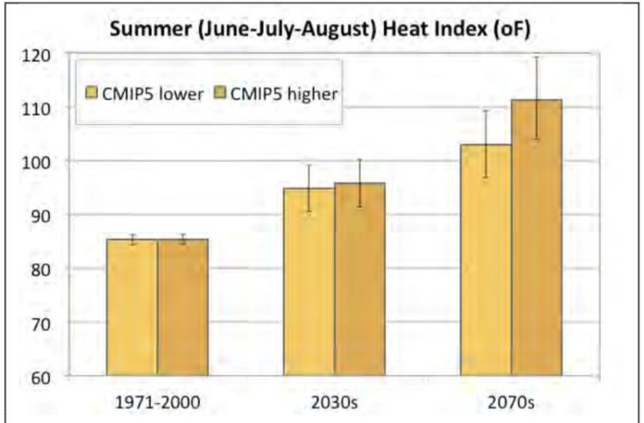
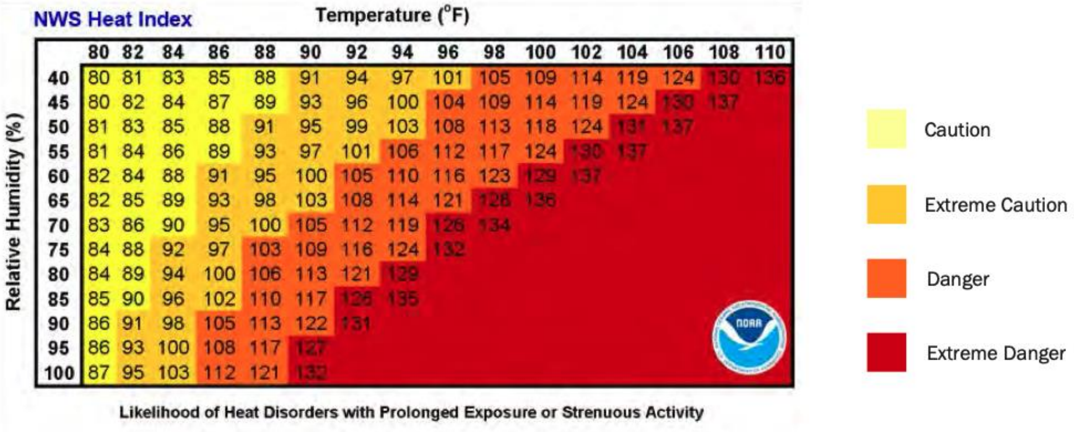


Figure 6. Historical and projected future summer heat index, based on projections for Boston Logan weather station (the nearest weather station with long-term humidity observations). Lighter gold bars show projected changes under lower scenarios and dark gold bars, under higher. Projections here are based on 8 CMIP5 models, as most CMIP3 models and one CMIP5 model did not have daily relative humidity projections available.



Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Fig. 14 **Heat Index Chart** (Source: National Weather Service NWS, NOAA)

Heat Index Above 90°F

Outdoor workers become more susceptible to heat-related illness.

Heat Index Above 100°F

Children, elderly adults, pregnant women, and people with underlying conditions are at heightened risk of heat-related illness.

Heat Index Above 105°F

Anyone could be at risk of heat-related illness or even death as a result of prolonged exposure.

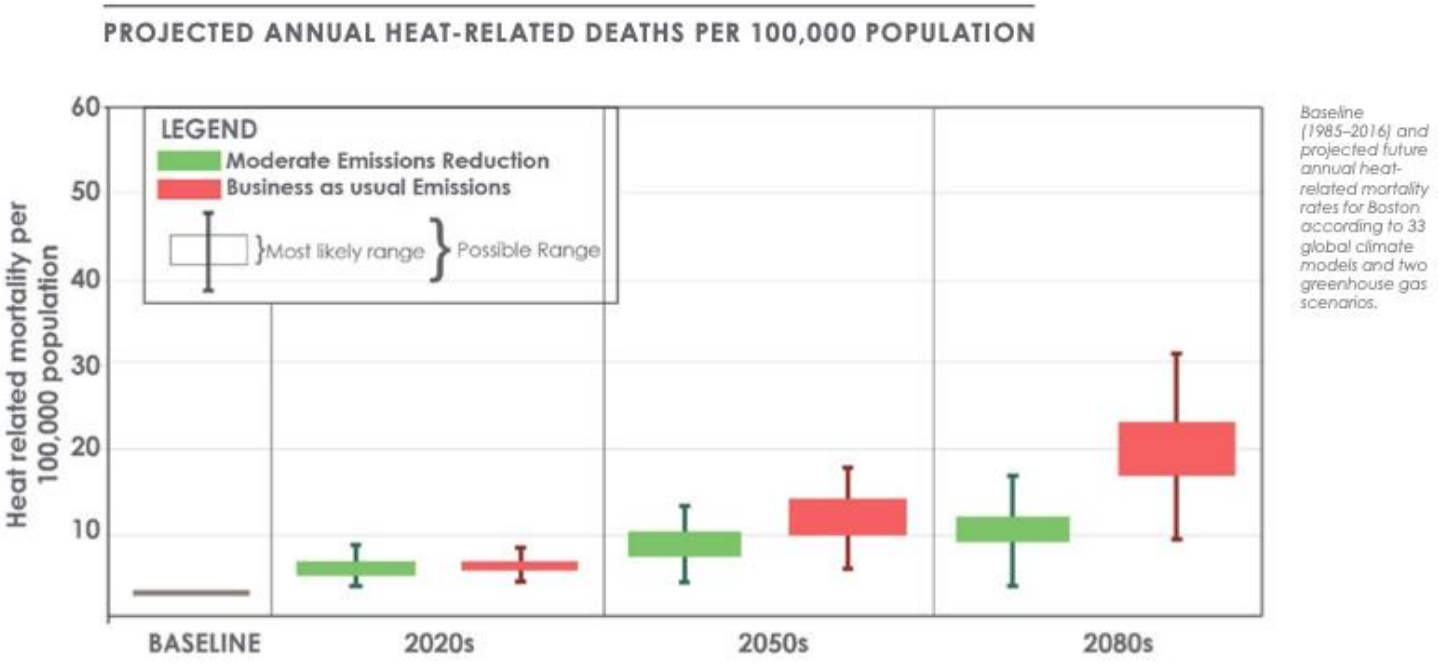
Heat Index Off the Charts

Undetermined: any level of exposure is presumed extremely dangerous for all people and likely to result in heat-related illness or even death.

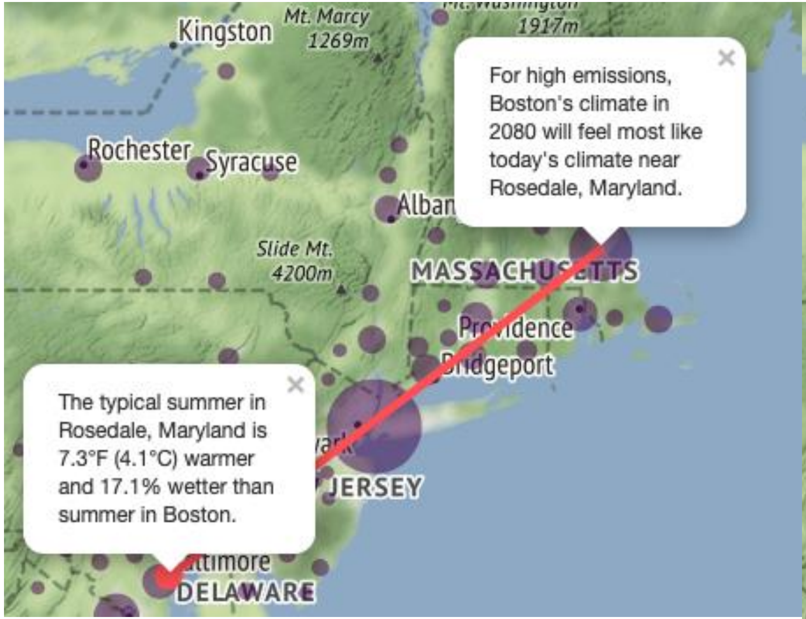
Left to right: AP Photo/Napa Valley Register, Lianne Milton; AP Photo/Julio Cortez; lzf/iStock; logoboom/Shutterstock

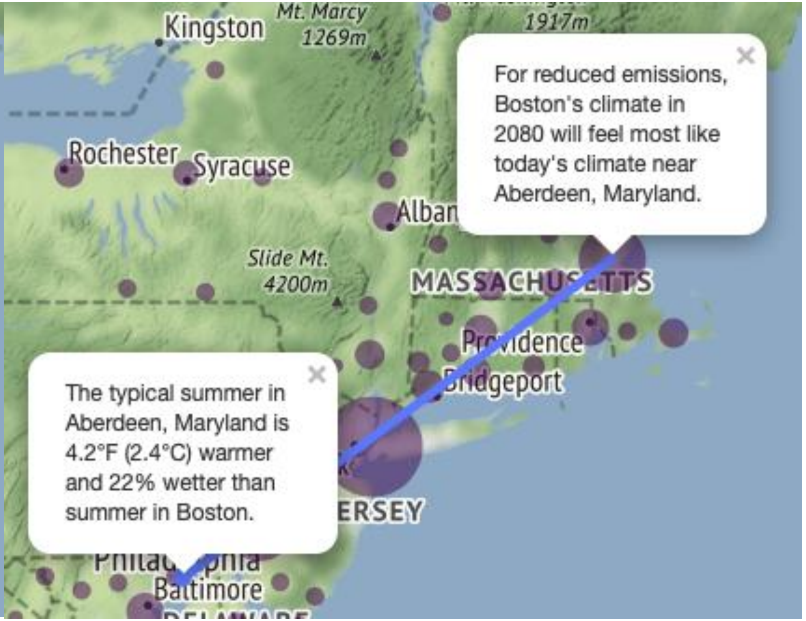
Fig. 4 **Priority Planning Areas Map** (Source: Kleinfelder, November 2015)

“Mortality rates due to extreme heat are expected to triple with the impacts of climate change in Boston.”

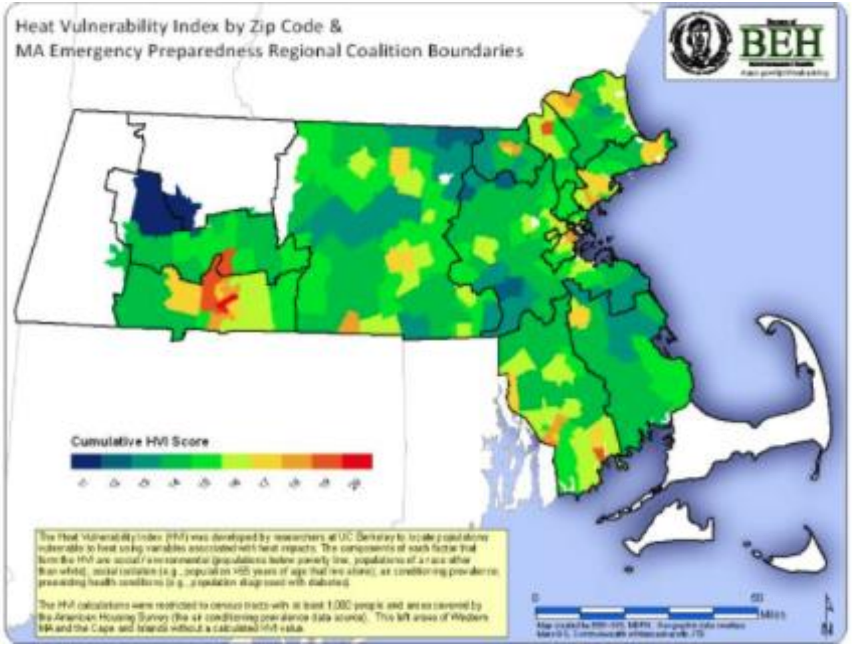


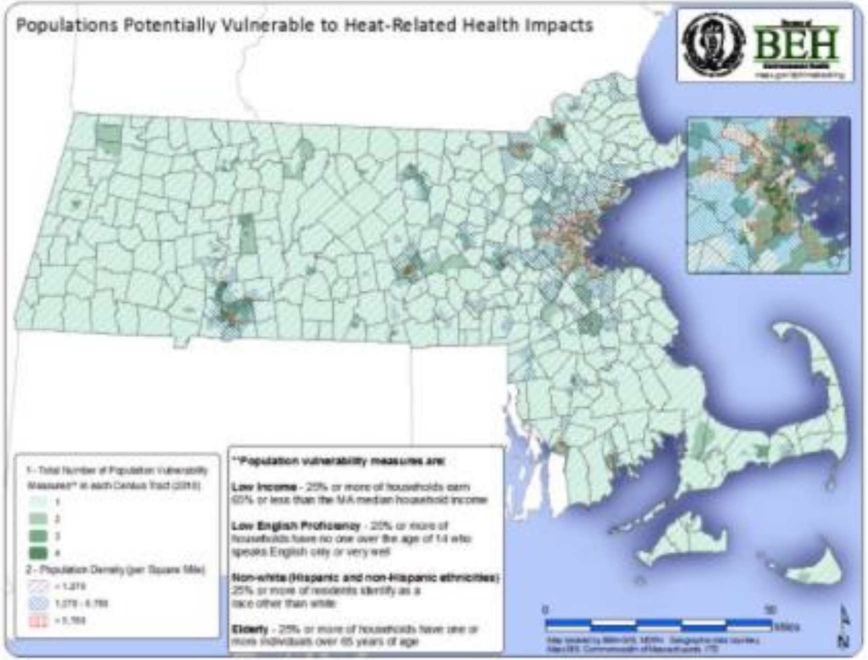
University of Maryland:
Center for Environmental Science





Resilient MA





“Housing as a critical determinant of heat vulnerability and health” – Science of the Total Environment

- HVI’s quantify and map relative distribution of risks to human health in the event of a heatwave – allows public agencies to identify highest risk neighborhoods, and concentrate emergency planning efforts and resources accordingly. Excluding building level determinates of exposure HVI’s fail to capture important components of heat vulnerability
- Building A/C and other characteristics are determinates of vulnerability. 50-85% of deaths during extreme heat events are associated with indoor exposure.

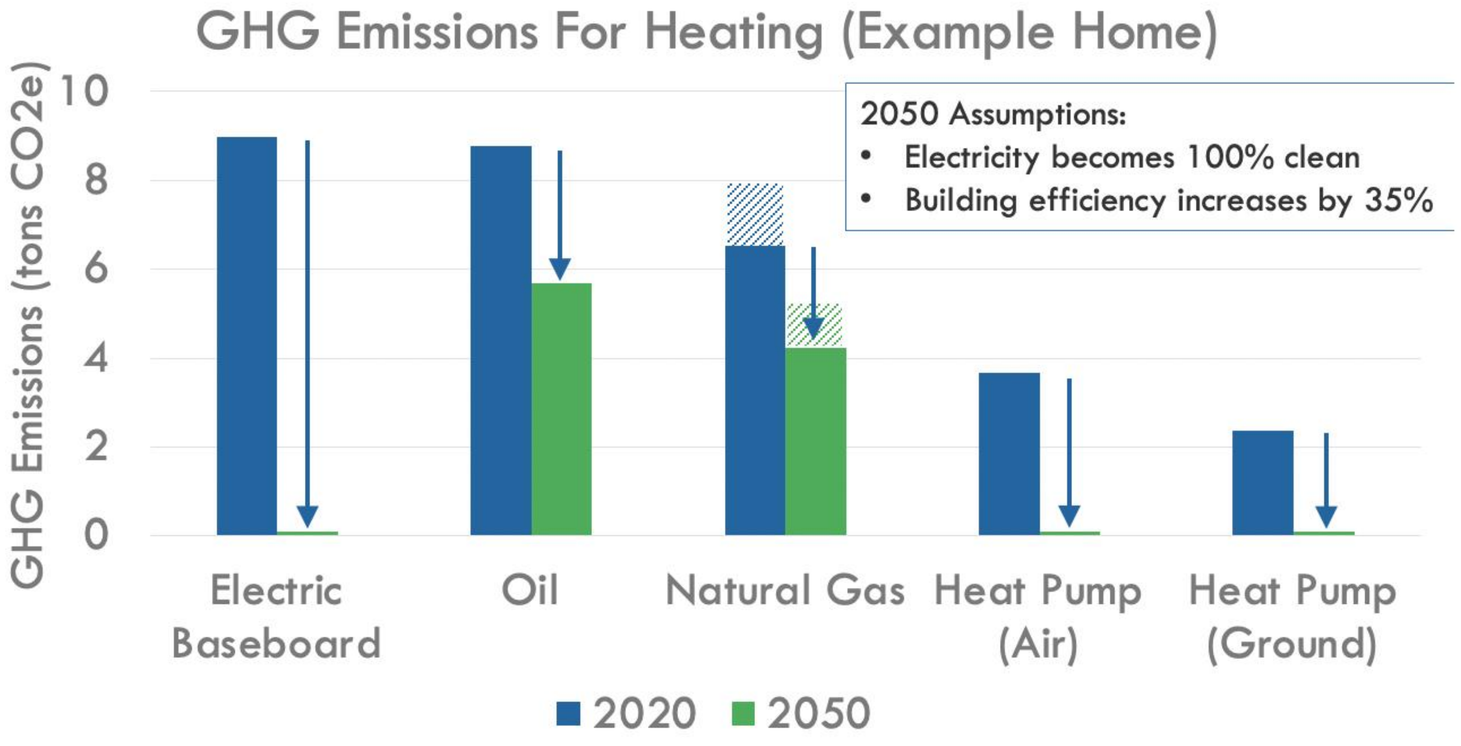
Buildings: Energy, Carbon, and Money

27%	**MA GHG emissions from fossil fuels used in buildings**
0% (net)	**Proposed 2050 MA emissions target**
2 million	**Number of buildings in MA**
500,000	**New buildings expected in MA by 2050**

WHY IS EVERYONE YELLING: "ELECTRIFY EVERYTHING!"

- We used to think "Natural Gas=Transition Fuel"
- But methane leaks from drilling sites and pipelines is 34 times more potent than carbon dioxide at trapping heat
- Estimated 1%-9% of natural gas produced escapes in extraction and leaking pipes, equivalent to the global warming emissions from 35 – 314 typical-sized coal power plants
- Electricity is getting cleaner and cleaner and will likely accelerate faster than scheduled

ELECTRIFICATION LEADS TO LOWER GHG AS GRID GREENS



“When you’re in a hole, the first thing is to stop digging… This bill simply takes away the shovel.”

- MA State Representative Tommy Vitolo

Image Credit: Adam Bindslev

IN POLICY REALM: SETTING THE RIGHT STAGE

- LEAN pays for **free mini-splits** in electrically heated buildings
- LEAN now covers **advanced air sealing** as a free measure- recent addition but ask for it- especially before you update heating or cooling
- MassSave needs mission to **not just be about cost effective efficiency** but also state climate goals
- **Push for state legislation to allow submetering** of VRF and billing tenants for portion of heating and cooling
- Federal government- should they be including a **cooling allowance** for our climate zone?

An Evaluation of Strategies for Adding Cooling

- Typically Passive approaches to reducing extreme heat are not enough (only takes the “edge” off)

- Cooling allowance limitation/limitations around sub-metering central systems

- COVID-19 adds complications to in-building/community cooling center approaches to extreme heat

An Evaluation of Strategies for Adding Cooling

Test Case: 50 unit building (split 1 and 2 bedroom units)

Strategy	Ballpark Cost/Unit	Ballpark Full Building Cost	Efficiency (EER/SEER)	Implementation Timeline
Window A/C	~$250 per A/C	$31,250	12.4	Immediate
A/C Sleeves	~$1,350 per A/C unit/sleeve	$67,500	10.6	Immediate (in buildings with sleeves)
PTHP	~$4,300/unit	$215,000	12.1	Replacement of existing PTAC system
Mini (or Multi) Split System	~$3,500 (1 indoor/1 outdoor) ~$6,000-$8,000/unit	$175,000 - $400,000	19.0	Retrofit
VRF	~$8500/unit	$425,000	19.0	Retrofit

Window A/C Units

- Tenant typically pays the utility cost to operate
- Best of building owner purchases and owns equipment

Benefits

- Inexpensive
- Immediately Implementable
- Removable
- Non-intrusive to the building envelope
- Behavioral zoning – Use only what is needed when it is needed

Challenges

- Limited to certain window types (double/single hung)
- Installation protocol (physical safety)
- Aesthetics
- Storage during heating season
- Limited distribution potential (need multiple units)

A/C Sleeves

- Mostly seen in existing buildings; not typically retrofit/new construction
- Tenant typically pays the utility cost to operate; building owner typically owns the equipment

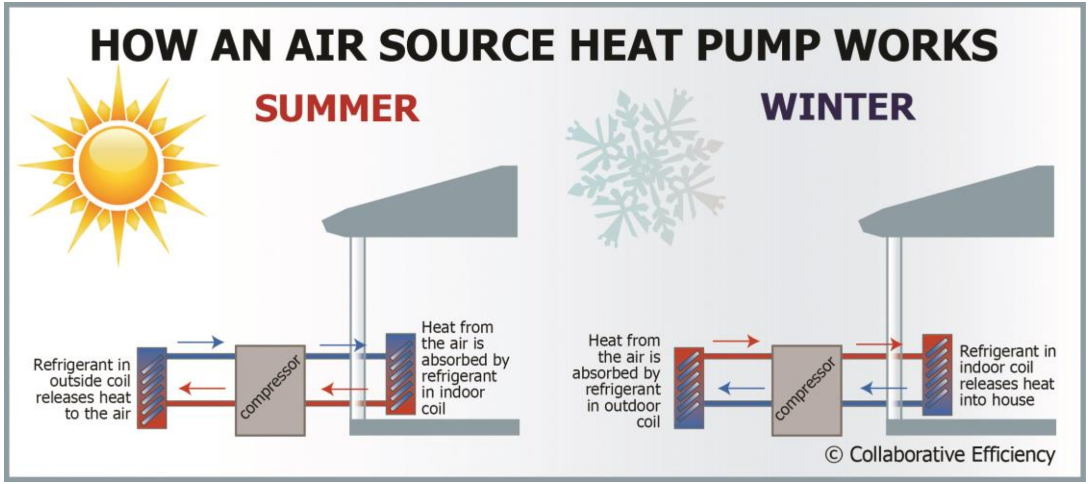
Benefits

- Inexpensive
- No interference with windows
- Winterize with unit in place

Challenges

- Penetration in the building air barrier and insulation layer
- Winterization required
- Aesthetics
- Limited distribution potential (need multiple units)

Heating and Cooling Air Source Heat Pumps



PTHP

- Retrofit of a PTAC system
- Cooling only or heating *and* cooling
- Tenant typically pays the utility cost to operate; building owner typically owns the equipment

Benefits

- Moderate expense
- No interference with windows

Challenges

- Penetration in the building air barrier and insulation layer
- Aesthetics (grill on outside)
- Limited distribution potential (need multiple units)

Mini Split Air Source Heat Pump

- *Cooling only approach*
- Tenant typically pays the utility cost to operate; building owner typically owns the equipment

Benefits

- Small refrigerant line penetration into unit
- Efficient
- Aesthetics (generally can hide outdoor units and refrigerant lines)

Challenges

- Placement of large number of outdoor units (either at grade or on roof)
- Cost
- Aesthetics/placement of indoor head

Mini or Multi Split Air Source Heat Pump

- *Heating and Cooling Approach*
- Tenant typically pays the utility cost to operate; building owner typically owns the equipment
- Could utilize in combination with existing heating system
- Important to reduce heating demand with other ECM’s

Benefits

- Electrification! Future carbon mitigation!
- Heating and cooling in one system
- “Residential” scale equipment for maintenance and replacement

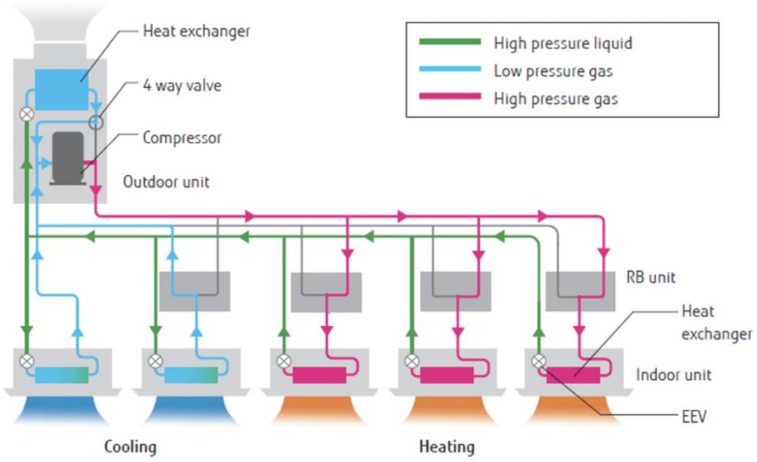
Challenges

- Capital Cost
- Integration with existing heating system and distribution (controls)
- Realization of manufacturers COP ratings
- Snow/Freeze Protection
- Heating operating cost*
- Potential for refrigerant leakage

Operating Cost Calculator

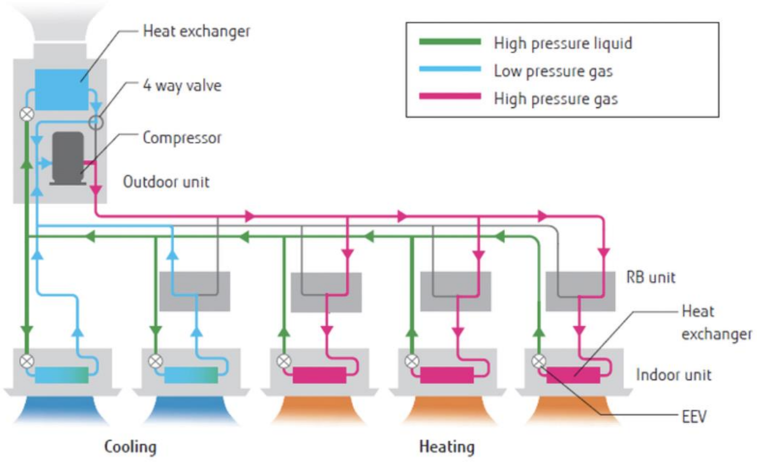
Inputs:			Notes
$/therm	$	1.20	
$/kwh	$	0.24	
Heating system efficiency		70%	A combination of equipment and distribution efficiency
COP of proposed electric heating system		2.0	
Calculations:			
Heating therms (billed)		700	therms
Btus (billed)		70,000,000	Btu
Btus (delivered for heat)		49,000,000	Btu
kWh required for an equivalent electric system		14,361	kWh
kWh required for an electric system at proposed COP		7,181	kWh
Outputs:			
Gas heating	$	840	
Electric heating (equivalent)	$	3,447	
Electric heating (COP = 2)	$	1,723	
Required electric coefficient of performance (COP) for electric costs to equal gas costs		4.1	
Electric is 2.1x more expensive than gas at a COP of 2.			

VRF Air Source Heat Pump



- *Heating and Cooling Approach*
- Typically owner pays utility cost to operate*
- Important to reduce heating demand
- Typically roof mounted central system with refrigerant lines to indoor units (wall mounted or ducted)
- Could utilize in combination with existing heating system
- “Heat Recovery” available to improve efficiency when some indoor spaces are in heating mode but others are in cooling, but typically results in a 30% increase in the cost of the system versus a baseline that does not do that heat exchange.

VRF Air Source Heat Pump



Benefits

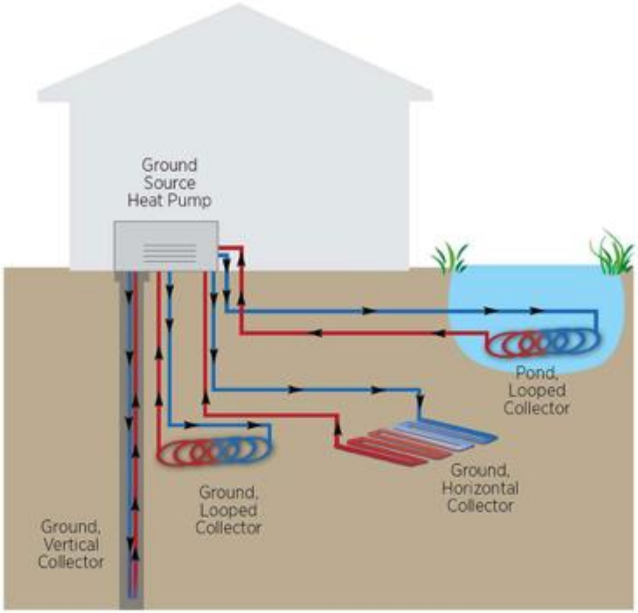
- Electrification! Future carbon mitigation!
- Heating and cooling in one system
- Less physical footprint on roof compared to mini-split systems
- Typically more professionally design and installed then mini-split systems

Challenges

- Capital Cost
- Integration with existing heating system and distribution (controls)
- Realization of manufacturers COP ratings
- Snow/Freeze Protection
- Heating operating cost*
- Potential for refrigerant leakage

Other Flavors of Heat Pump Electric Heating and Cooling

- Air to water VRF system
- Ground Source Heat Pump (GSHP)



Thank You!