Stakeholder Charrette Report

Charrette #4: Building Retrofits | April 21, 2021

Char-rette: a meeting in which all stakeholders in a project attempt to resolve conflicts and map solutions

Background

Decarbonizing the way we heat and cool our buildings is essential to a stable climate and a zero-emissions future.

HEET[1], a non-profit climate solutions incubator, has designed a method for gas utilities to deliver renewable, non-emitting and non-combusting heating and cooling. This technology, known as networked geothermal[2], consists of pipes filled with water that are installed in the street and connected to ground source heat pumps in buildings. The system can be installed and operated by existing gas utilities, providing a way forward for a transition off natural gas and for states and municipalities to meet emission reduction mandates.

Increasingly, utilities and energy advocates across the U.S. and internationally are considering networked geothermal as a viable electrification pathway, business model and alternative to fossil fuels. In Massachusetts, six networked geothermal demonstration projects have been approved for installation and are moving forward.

Each of HEET's charrettes is an ongoing effort to work together across diverse perspectives and backgrounds, generate ideas and anticipate barriers. In this way, we can move towards a just energy transition—one with clean, safe and accessible energy, low customer bills and good jobs—as rapidly, wisely and justly as possible.

Executive Summary

At HEET's Building Retrofits Charrette, participants shared approaches and best practices for retrofitting buildings as they transition to ground source heat pumps for residential heating and cooling in networked geothermal installations. The charrette included presentations by

[1] HEET, Home Energy Efficiency Team, is a Massachusetts-based non-profit dedicated to cutting carbon emissions now by driving systems change.
[2] Networked geothermal is also commonly referred to as thermal energy networks. In the past, it has been called the GeoMicroDistrict or GeoGrid.

speakers experienced in making buildings more energy efficient and in installing heating and cooling equipment.

The 50 stakeholders present included utility executives, regulators, labor and workforce representatives, community organizations, advocates, geothermal designers and installers, and heat pump installers and manufacturers.

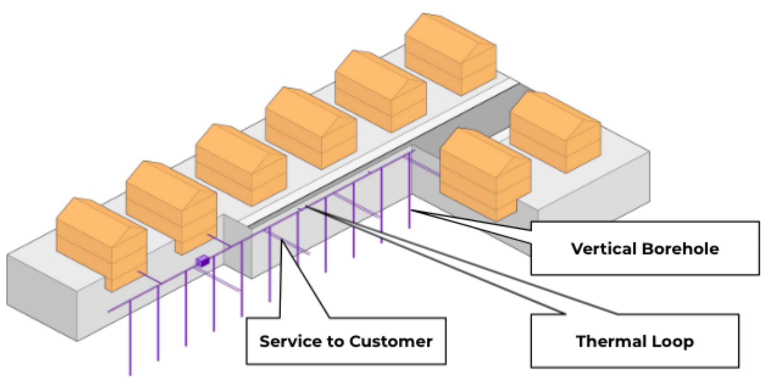
Key takeaway: Most buildings will need new HVAC (heating, ventilation, and air conditioning) equipment as they are brought into networked geothermal systems. Conversion plans will need to be optimized to the existing, variable conditions of different buildings. Including utility-owned heat pump equipment could speed up conversion and help utilities manage the system in the long term.

HEET deeply thanks all participants for their input. This report will be shared with participants and other stakeholders, including utilities and state regulators.[3] *HEET also thanks E4theFuture and other funders for their support of HEET's charrettes.*

Introduction

HEET's Co-Executive Director, Audrey Schulman, opened the charrette. Schulman explained the concept of networked ground source heat pumps, or networked geothermal.

Networked geothermal requires thermal management to ensure the water in the ground loop of pipe stays roughly within a 40 to 90 degree Fahrenheit temperature range. This allows heat pumps in buildings to function at their greatest efficiency.



Each building connected to the system can pull off the heating or cooling it needs. Excess thermal energy is stored in underground bedrock until it's needed.

Schulman posed the question of how to retrofit buildings attached to a networked geothermal system in a way that minimizes costs and disruption.

Zeyneb Magavi, HEET Co-Executive Director, explained that the scope of the charrette's

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discussion would be solely on the mechanics of HVAC retrofits needed in buildings. Magavi named other important topics that will be tackled in future HEET charrettes, including: workforce development considerations, how to transition non-HVAC appliances, electric capacity and financing options.

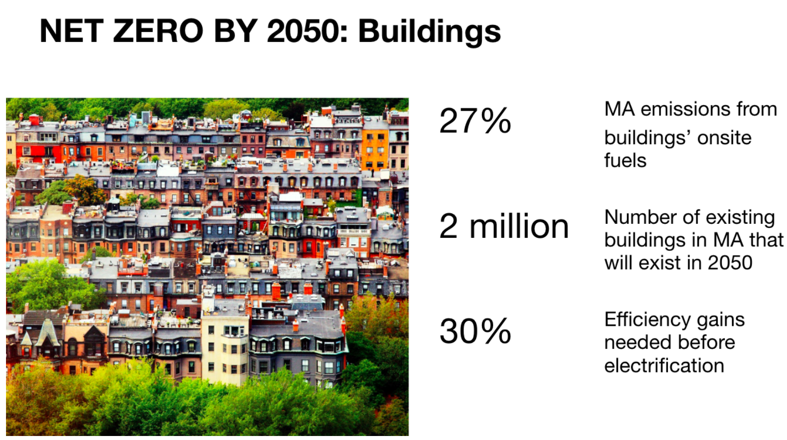
Presenters

- **Beverly Craig**, Senior Program Manager at Massachusetts Clean Energy Center (MassCEC)
- **Orest Manzi**, Manager of Statewide Energy Program Field Operations at Action for Boston Community Development, Inc. (ABCD)
- **Jason Taylor**, Air-Sealing Specialist and Instructor at Green Jobs Academy, Byggmeister Associates
- **John Ciovacco**, President of Aztech Geothermal
- **Cary Smith**, US Managing Member at GreyEdge Group and owner of Sound Geothermal Corporation

Beverly Craig

Beverly Craig coordinates low and moderate income programs at Massachusetts Clean Energy Center (MassCEC). MassCEC supports the state's goals of reducing greenhouse gas emissions by providing clean energy and energy efficiency resources.

> In Massachusetts, buildings produce 27% of statewide emissions. On-site building emissions are greater than the state's entire electricity sector. More than half of these buildings are heated with gas.



> To achieve the Commonwealth's 2050 net zero emissions goal, it is imperative to transition buildings off of gas to efficient electric appliances and then source that electricity from renewable energy. This will require retrofitting the more than two million buildings in the state, the vast majority of which were built before 2020.
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> Heat pumps (whether networked or not) pose a promising solution: they are energy efficient and can accomplish heating electrification on a wide scale. However, for heat pumps to work effectively, we must improve the thermal efficiency of older leaky buildings by an average of 30%.

> For homeowners in Massachusetts, Mass Save is a great place to start. The state-sponsored program provides low or no-cost energy efficiency upgrades, including insulation and air sealing. Depending on the previous condition of a building, insulation can reduce heating bills up to 40%, while also increasing comfort. For one to four-family homes, Mass Save pays 75–90%[4] of the insulation cost by default. For low-income owners and tenants, the local Community Action Program (CAP) agencies will pay 100% of the cost.
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> Much of the existing housing stock is three to four times more drafty than new buildings. In these older buildings, it is critical that holes where the drafts enter are air-sealed before insulation is installed. MassCEC provides a checklist of questions that homeowners can use to help direct Mass Save auditors towards more thorough work, especially in air sealing.

Orest Manzi

Orest Manzi is the Manager of Statewide Energy Program Field Operations at Action for Boston Community Development, Inc. (ABCD). He has extensive experience retrofitting buildings and installing heat pumps, primarily in low income homes.

> Heating with combustion, such as a furnace or boiler, delivers temperature quickly but inefficiently. Heat pumps, on the other hand, move temperature slowly but efficiently. When each housing unit is properly insulated and air-sealed to reduce drafts, heat pumps work at their greatest efficiency, keeping the indoor temperature comfortable and consistent.
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> A ground source heat pump (GSHP) uses water to pull temperature from the ground. It can distribute that temperature through a forced air system (i.e. air ducts) or a hot water distribution system (i.e. hot water radiators or a baseboard water heater). There are two main types of GSHP systems: water-to-air and water-to-water.
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> **Water-to-air (i.e, the building has air ducts):** In this model, GSHPs connect to existing forced air systems. This tends to be the easiest and least expensive retrofit, especially where there is also access to an open basement and open attic.
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> **Water-to-water (i.e, the building has radiators or hot water baseboards):** In this model, GSHPs connect to hot water systems, which use metal pipes or radiators to deliver heat to rooms. They cannot deliver cooling, as it would create condensation on the metal and nearby floor and wall, causing mold. If residents want air conditioning, Manzi recommends installing wall or ceiling cassettes, also called ductless mini splits. These connect to a heat pump with “split” refrigerant lines and individual condensate lines, which may be easier to run through the building than forced air ductwork.

[4] This was the rebate at the time of the charrette. Rebates change constantly. Starting in 2021, 2 to 4 family homes began receiving a 100% insulation rebate.

Water in a GSHP hydronic boiler runs at a lower temperature than most gas boilers. For some hot water retrofits, Manzi recommends replacing radiators with high output baseboards for heating, then adding centralized cooling in a few rooms.

Retrofits can run from $20,000-$55,000 per home, depending on the complexity.

Another important consideration in retrofitting is proper sizing of the HVAC equipment. Many HVAC installers match the new equipment to the existing equipment, despite the fact that the original design may have been oversized.

Since this technology is new and evolving, it poses a generational shift in the HVAC approach and requires new training and modeling equipment for contractors and installers.

Jason Taylor

Jason Taylor has been training green job workers for the past 12 years at the Green Jobs Academy, the ABCD Weatherization Lab in Mattapan and at Roxbury Community College. He has written air-sealing curricula for community colleges, Massachusetts Association for Community Action and HEET.

Heat most often leaks from the tops of buildings, sucking cold air in from any leaks at the bottom of a building in what is known as the “stack effect.” For a comfortable and efficient indoor environment, these leaks must be sealed completely.

The colder it is outside, the stronger the stack effect will be. If there are holes near the top of a house or in ceilings, physics tells us that the warm air will move up and out. An air source heat pump will not work as well in these conditions because it has to fight this heat loss. Reducing drafts, or air sealing a building, is essential for an air source heat pump to work effectively.

Zonal pressure diagnostics (ZPD) is a useful tool to find holes in a home. Performing the ZPD calculation adds about five minutes to a regular blower door test.[5]

[5] A blower door test is a method where a large fan is placed in an exterior door, depressurizing a building to 50 pascals and measuring the cubic feet per minute air flow through the fan. This test can be used to quantify how leaky a building is before and after sealing work and to help pinpoint leaks.

There are several important places that are commonly overlooked in air sealing a house. Sealing these can result in 10% savings on the heating load. Mass Save covers 7, 8, and 9 on this list:

1. Recessed lights
2. Finished attic
3. The area where a new addition joins an existing building
4. Flat roofs
5. Cathedral ceilings, especially with recessed lights
6. Dormers
7. Ducts
8. Knee Walls
9. Skylights

Heat pumps are an unfamiliar technology for many homeowners. In general, a bit of adaptation is required to use air source heat pumps effectively, summed up by the acronym DIOS:

Design: Air source heat pumps that are too big are inefficient and use a lot of electricity on warmer days. Heat pumps that are too small can't keep up with the heat required on cold days. Equipment has to be sized just right. Proper modeling of an individual house's heat loads is very important.

Installation: Flare joints can leak when not installed properly. Heat pump manufacturers demand certain pressurization tests that are not always performed properly by HVAC installers. Also make sure leaking refrigerants are checked according to best practices.

Operation: Because heat pumps collect heat from the cold outside, they work best when they run at a slow and consistent rate. Though it seems counterintuitive, running heat pumps at a steady temperature uses less energy.

Scheduled Maintenance: Like oil heating systems, heat pumps need to be serviced once a year. Filters should be changed and refrigerant levels checked.

An air source heat pump installed without these criteria will struggle to heat a home on the coldest days and may require back up. **Ground source heat pumps,** like those used in a networked geothermal system, avoid this issue by pulling heat directly from the earth through water that moves through underground pipes.

Cary Smith

Cary Smith has extensive experience in all facets of the ground source industry and heat pump installations. He is the U.S. owner Sound Geothermal Corporation and Operations Manager for the Grey Edge Group.

When a building is well insulated, another problem can occur: lack of ventilation. One solution to this is to install an energy recovery ventilation (ERV) system to address any issues with moisture and odor. This system can be installed in existing bathroom vents. It recovers up to 84% of thermal energy (i.e. the heating or cooling) from the used air and transfers it to the fresh air, reducing wasted energy while improving ventilation. ERV can use up to 25% of the building's electric needs, so this should be factored in when determining electrical system requirements.

Analyzing energy demand and load over time can help determine the proper design and sizing of a system. Typically, for 90% of the year, any system is running at half its capacity. For the remaining 10% of the year, the system is running at full capacity (called peak electric load) and is using much more energy per hour. One method to increase efficiency of the system for the majority of the year is to design the system to be smaller, while meeting the 10% peak needs with a back-up system.

In any design, resiliency and redundancy are essential. These were incorporated into Weber State University's district energy system in Utah. Sections of the system have the ability to be isolated and operate independently, allowing other parts to continue running if something goes wrong. In addition, Weber State's system takes advantage of load balancing, or transferring energy between areas to shed heat and cool down or add heat to warm up.

John Ciovacco

John Ciovacco is the President of [Aztech Geothermal](), LLC. Ciovacco often serves as a resource to building owners, developers, construction companies, engineers, architects and investors regarding the latest renewable and energy efficiency technologies, government incentives and financing options. Aztech Geothermal has converted hundreds of existing central forced air combustion furnace systems to electric heat pumps.

When converting air ducts from a furnace to a heat pump, there are several things to keep in mind. The size and air flow of the existing ducts may not be appropriate for a heat pump. Heat pumps often require more air flow than older combustion furnaces to effectively deliver heat and cooling to a building. Simply increasing the heat pump fan speed to force more air flow through undersized ductwork often results in excessive noise and increased energy use.

> The first step in sizing a system correctly is completing a site assessment. A contractor will take measurements of all the rooms in a building, including the size and location of air registers and existing ductwork. Sealing any drafts, which can be located using a blower-door test, will make a building more efficient, reducing the size of the heating system and ducts needed.
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> After the site assessment, the next step is to calculate an accurate energy model using the ANSI/ACCA Manual J standard, which is required for submission of rebates in most states with incentive programs. After the energy model is completed, the heat pump can be selected.
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> Finally, ductwork sizing is determined to see if any modifications are needed.

Discussion and Attendee Comments

HEET asked charrette participants in an online poll to state the biggest challenges in retrofitting buildings. Responses included the following:

- Ensuring the building HVAC is adequate to achieve desired temperatures.
- Establishing standards, as one size does not fit all in the Northeast housing stock.
- Making sure there is 100% accessibility for every income level.
- Retrofitting high temperature (hot water and steam) systems.
- Designing for a wide range of building specific design and install challenges.
- Dealing with older buildings and lack of weatherization.
- Overcoming disruption to communities and residents.
- Convincing people to adopt new systems, including contractors and individual building owners.
- Performing qualified assessments of current conditions for proper design.
- Finding a qualified vendor who you can understand.

Finally, participants were asked to share: What do you think is the greatest innovation needed in building retrofits? The following ideas were submitted:

- Have a uniform system that can be applied across buildings that need retrofitting, with simple customization.
- Avoid interior distribution work by running new insulated piping on exterior walls, with a new curtain wall and then penetrating piping into building spaces. (Example: Energiesprong in the Netherlands and Casa Passiva approach in NYC).
- Combine renewable sources to work together efficiently, such as solar integrated into networked geothermal systems.
- Leverage solar gain through thermal mass of masonry walls combined with earthen tubes in connected suburban backyards.

- Persuade the state government to think about how to catalyze the scale of change needed to achieve MA's net-zero mandate and the emission reduction goals specified in the 2030 Clean Energy and Climate Plan.
- Design a poly-modal heat pump system that can retrofit an ASHP to be a dual fuel system—ground source or air source.
- Share lessons learned widely and publicly.

Additional Information:

HEET slide deck

For more information about HEET and its work on networked geothermal:

https://heet.org
https://heet.org/who-we-are/our-people/
https://heet.org/geo/
https://heet.org/community-charrette-reports/
https://heet.org/library/

Other references:

MassCEC: https://goclean.masscec.com/
MassCEC weatherization checklist: https://goclean.masscec.com/wp-content/uploads/2021/03/Weatherization-Checklist.pdf
Department of Energy explanation of a blower door test: https://www.energy.gov/energysaver/blower-door-tests
Air Conditioning Contractors of America Manual: https://www.acca.org/news/release/acca-2016-manual-j-recognized-by-ansi