Eversource Geothermal

Framingham Pilot Project

Tim Ashmore
ashmoret@cdmsmith.com

Eric Bosworth
Eric.Bosworth@eversource.com

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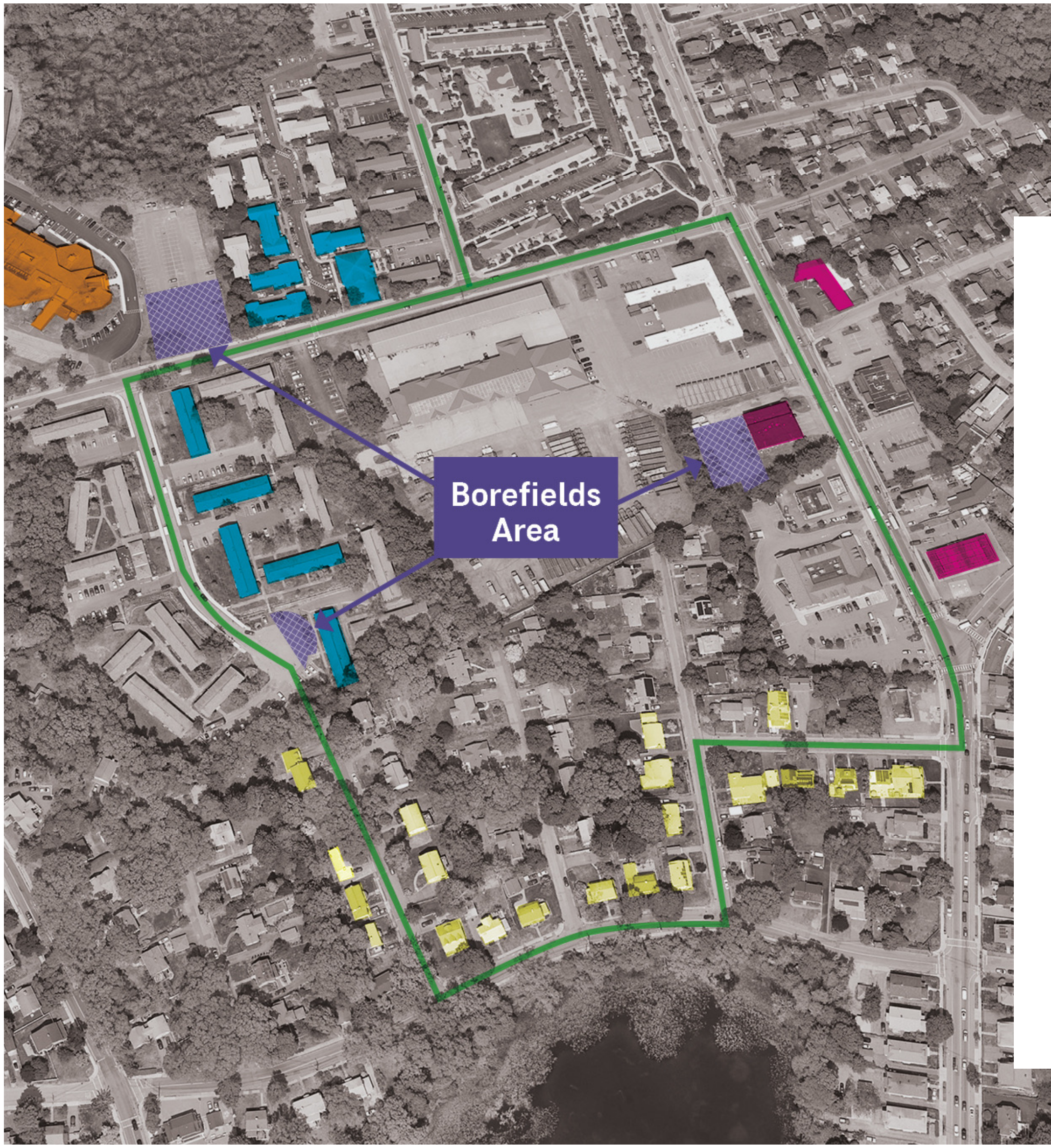
EVERSOURCE CDM Smith

Agenda

1. Project Overview
2. Regulatory Process & Commercial Structure
3. Geothermal Network Process Flow
4. Geothermal Borefield
5. Energy Modeling
6. Alternatives Analysis & Engineering Decisions
7. Construction Details & Building Conversions
8. System Performance
9. Lessons Learned
10. Next Steps & Future Business Cases

Learning Objectives

- Current best practice for system components and layout
- Data needs to properly model the system
- How base construction costs compare to system expansion costs
- Nuances of the building retrofit challenge
- Future considerations



Project Overview

- One main and two recharge borefields
- Primarily Environmental Justice Community
- Mix of loads for system balancing
- 1+ mile of ambient loop piping
- Six outside stakeholders to integrate

Framingham Project Background

Eversource’s Approved DPU Order

Pilot Objectives

Emissions: Reduce carbon emissions and align to Massachusetts Global Warming Solutions Act

Scalability: Obtain insights regarding the scalability of a cleaner, safer technology

Environmental Justice: Target low-income, multi-family buildings in a dense geographical footprint with mixed loads to evaluate efficiencies of a geothermal network

Expanded Rate Base: Evaluate the ability to remove consumers from delivered fuels

Pilot Parameters

Assets: Eversource covered 100% of conversion costs for residents and commercial customers alike

Ownership: Residences and commercial customers own and maintain the in-building equipment

Economics: Small fee charged to customers quarterly

Customer: Customer protection plan to guarantee savings as electric consumption increases

Commercial Model (Value Prop)

Utility

- Provide customers an additional choice/alternative for heating
- Potential new business line
- Capitalize on existing gas company core competencies
- Flatter load profiles, higher utilization of infrastructure

Customer

- Provide low-cost heating where gas is not available
- Cleaner, quieter and reliable system
- Geothermal customer equipment is located inside the building so there is an ease of repair/maintenance and no aesthetic impacts

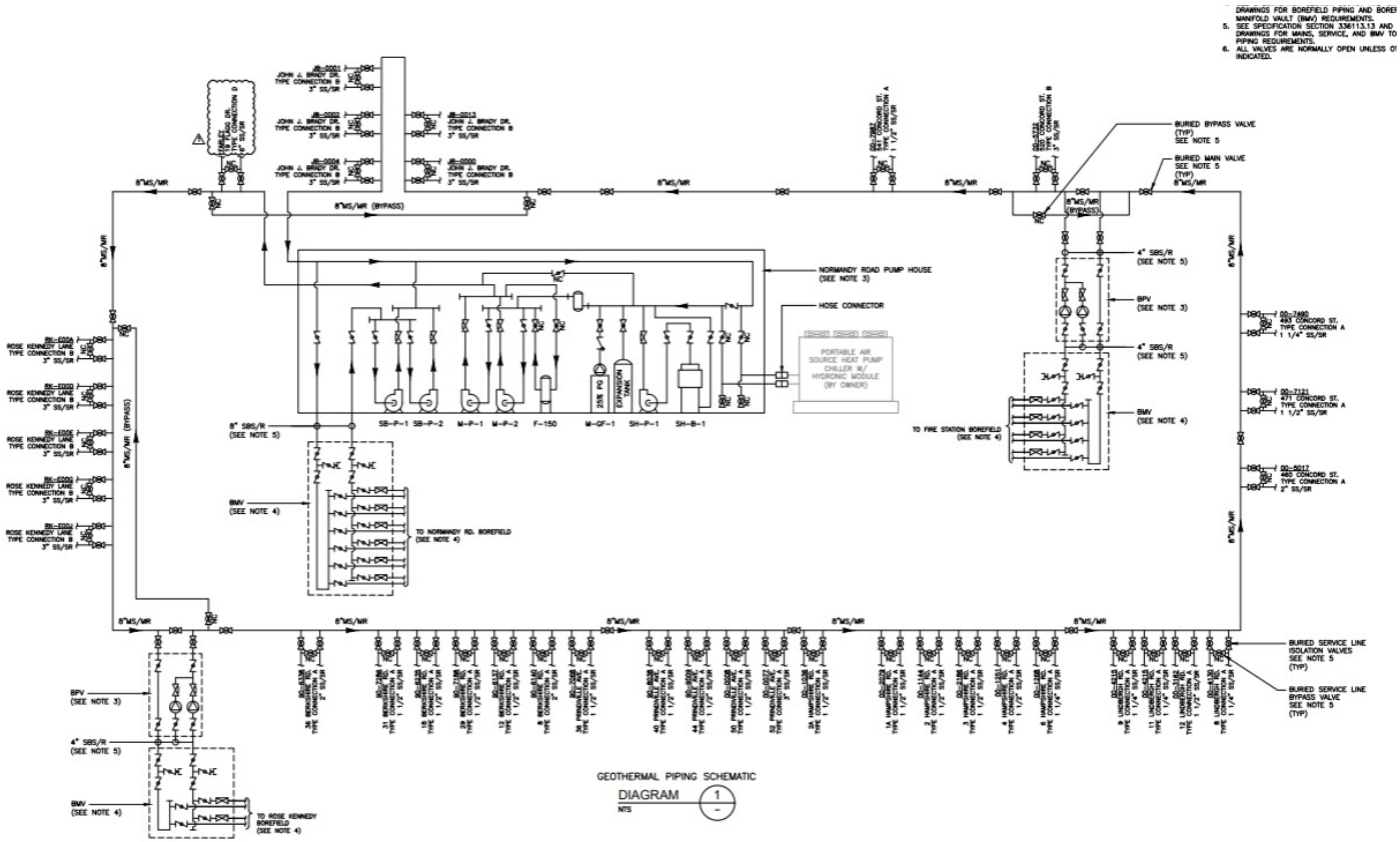
State

- Provides state with another way to meet climate goals
- Estimated 60%+ reduction in carbon emissions from combined heating and cooling for an average residence by installing geothermal

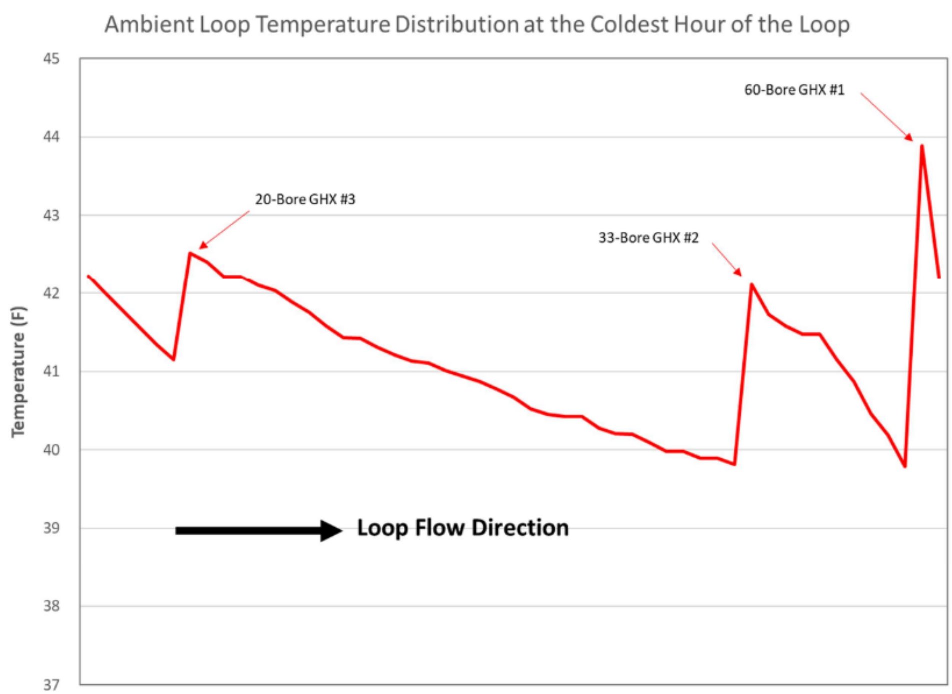
Technical Learning Objectives

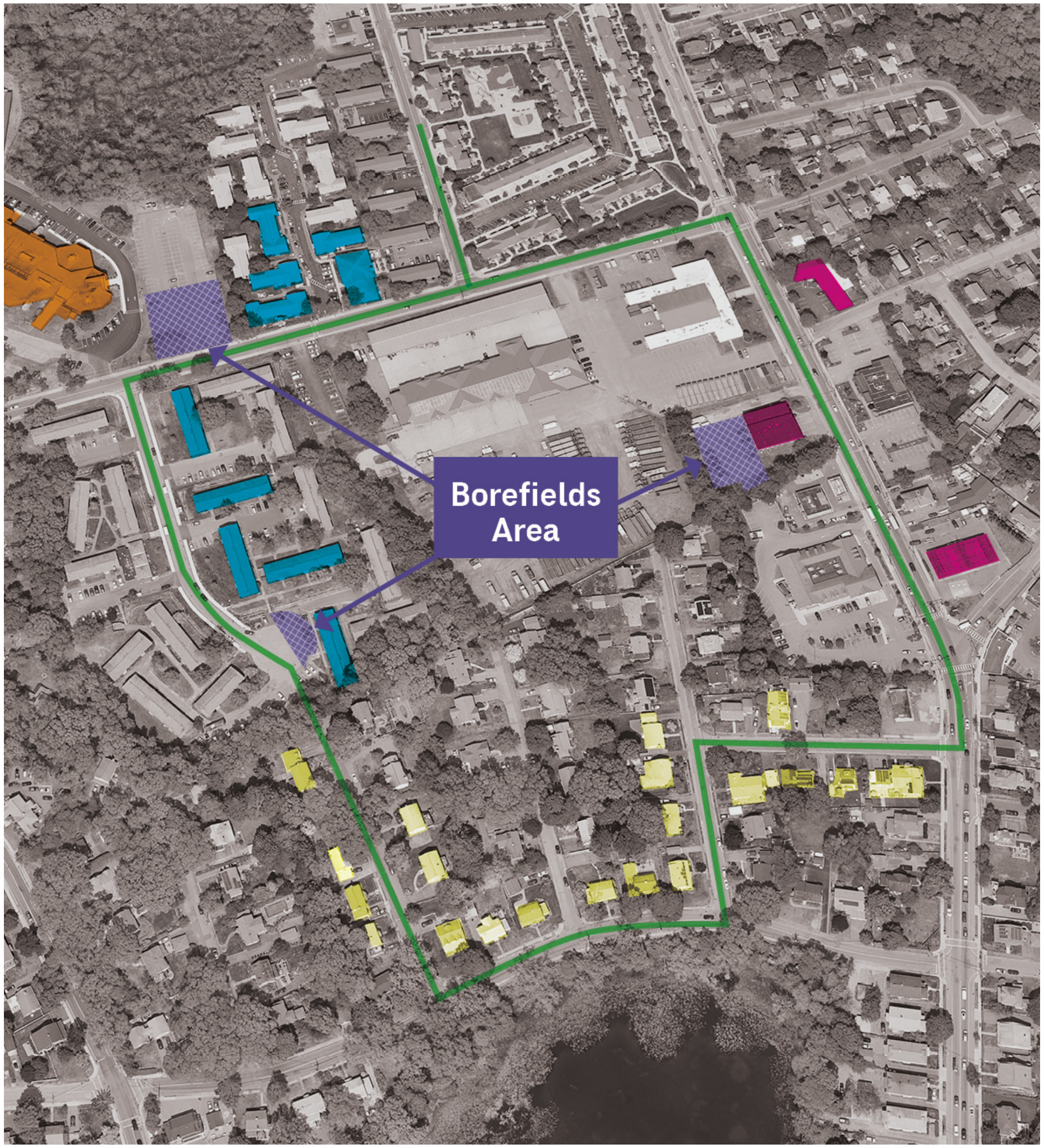
Success Factors	Data Points to Collect
Validated installation and operating costs	• System installation costs • Ongoing O&M costs
Customer acceptance of technology	• Customer Satisfaction surveys • Customer comfort
Environmental Benefits	• Emission reductions • System efficiency
Technology performance	• System performance • Changes in customer energy consumption
Cost savings	• Changes in customer heating and cooling costs

System Overview



Borefield Needs





Energy modeling

Monthly Load Data

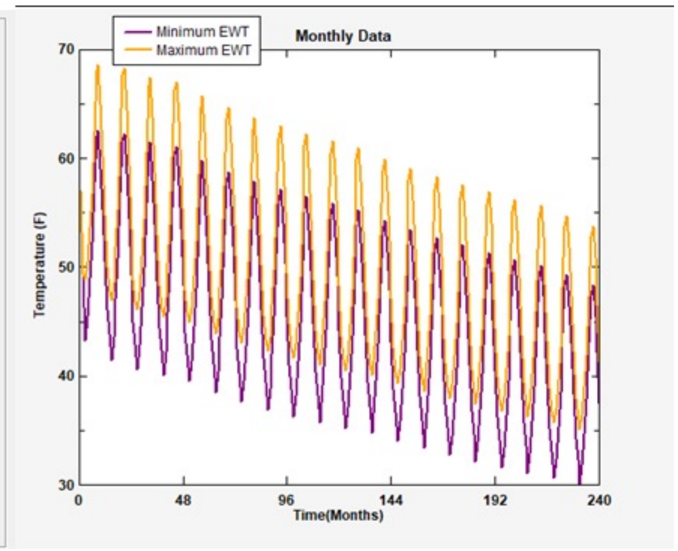
Update | Cancel

	Cooling		Heating	
	Total (kBtu)	Peak (kBtu/hr)	Total (kBtu)	Peak (kBtu/hr)
January	1804	34	2278697	9975
February	416	28	2121224	9060
March	15676	1442	1743004	6573
April	85668	1953	1121420	5266
May	305959	3639	667389	3259
June	998451	6040	422178	1916
July	1614522	6311	368986	1260
August	1492854	6270	349074	1170
September	718432	4630	394460	1852
October	226948	2696	628128	3637
November	12681	382	1321971	6508
December	4620	35	1971595	7056
Total:	5478030	3.0 Hours at Peak	13388127	3.0 Hours at Peak

Flow Rate 3.0 gpm/ton

Unit Inlet (°F): 90.4 | 35.4

	COOLING			HEATING		
	Design Day	Monthly	Hourly	Design Day	Monthly	Hourly
Total Bore Length (ft):	200000.0	200000.0	--	200000.0	200000.0	--
Borehole Number:	400	400	--	400	400	--
Borehole Length (ft):	500.0	500.0	--	500.0	500.0	--
Ground Temperature Change (°F):	-1.2	--	--	-1.2	--	--
Peak Unit Inlet (°F):	76.2	68.6	--	36.2	30.0	--
Peak Unit Outlet (°F):	85.6	74.2	--	30.8	24.6	--
Total Unit Capacity (kBtu/Hr):	8832.0	6310.6	--	9974.7	9974.7	--
Peak Load (kBtu/Hr):	6310.6	6310.6	--	9974.7	9974.7	--
Peak Demand (kW):	371.7	301.2	--	950.1	1063.2	--
Heat Pump EER/COP:	18.2	22.7	--	3.2	2.8	--
System (Seasonal) EER/COP	17.0	122.4	--	3.1	3.6	--
Avg. Annual Power (kWh):	--	4.48E+4	--	--	1.09E+6	--
Equip. Flow Rate (gpm):	2208.0	1577.6	--	2493.7	2493.7	--
System Flow Rate (gpm):	1577.6	1577.6	--	2493.7	2493.7	--



Alternatives Analysis & Engineering Decisions

Loop designs were considered with a number of criteria in mind:

Option	Advantages	Disadvantages
Two-pipe	▲ Consistent, predictable water temperatures to each building ▲ Works well with large, centralized bore field which avoids downtime and simplifies water / cuttings management ▲ Centralize location of thermal balancing with boilers / dry coolers	▼ Larger Central Pumping Requirements that account for service line heat exchanger pressure drop ▼ More challenging with setbacks to other buried utilities in ROW ▼ Less expandable to neighboring thermal networks ▼ Less opportunity for redundancy and resiliency with central ground loop location
One-pipe	▲ More expandable to neighboring networks in almost all directions ▲ More opportunity for redundancy and resiliency with distributed thermal recharge ▲ Less distribution piping between buildings / in the street with less space required within ROWs ▲ Lower first cost for lateral piping & installation ▲ Lower central pumping energy resulting in lower flow rates and smaller pipe sizes for distribution piping ▲ Connection on either side of the street without crossovers ▲ Can incorporate various types of thermal sources and sinks specific to the site (surface water, wastewater/sewer, horizontal ground loops, etc.) ▲ Requires distributed recharge	▼ Requires distributed recharge to have equitable entering water temperature (EWT) ▼ Requires service line pumps, buildings, and recharge field ▼ Vertical heat exchanger drilling will impact more customers ▼ Can result in greater number of access points (man-hole covers, etc.) or would require building access to service in-line pumps

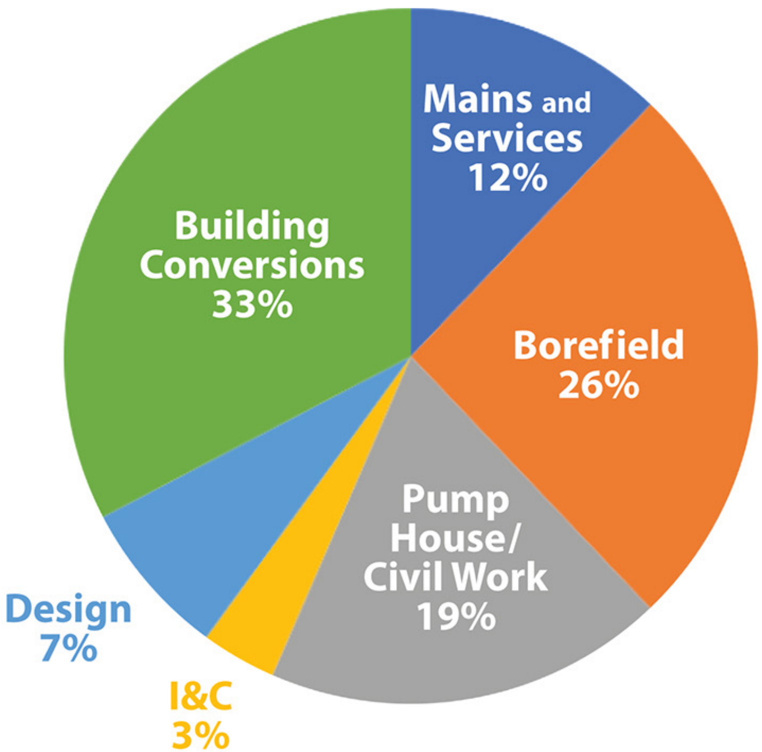
- One Pipe vs Two
- Pumping Energy
- Overall Efficiency
- Glycol Cut
- Temperature Variation
- Ease of Expansion
- Cost and Construction Scope

Other Key Decisions

- Backup power
- Domestic Hot Water
- Redundant Heating

Pilot Project Cost Analysis

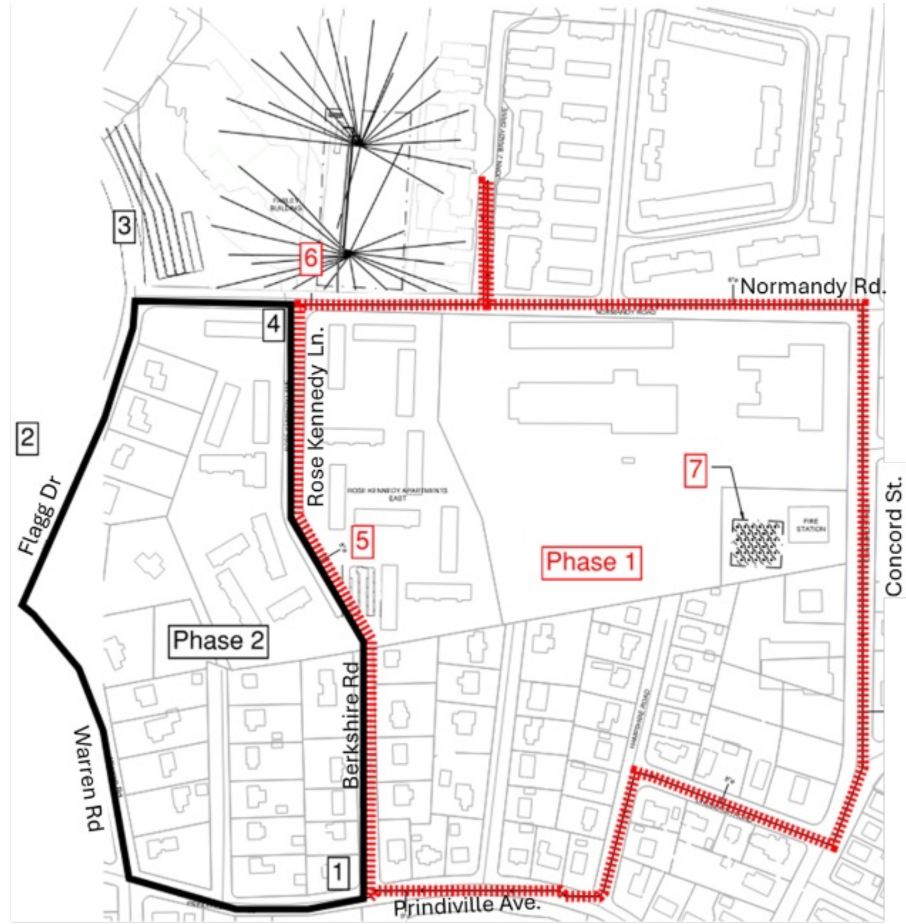
Current Pilot Cost Breakdown



- Main and service work almost identical to traditional pipe installation costs
- Pump house and civil work will be a mostly fixed cost regardless of system size
- Design costs will improve with experience and existing drawing sets to work from
- Major project costs end up being the building conversion work and borefield drilling

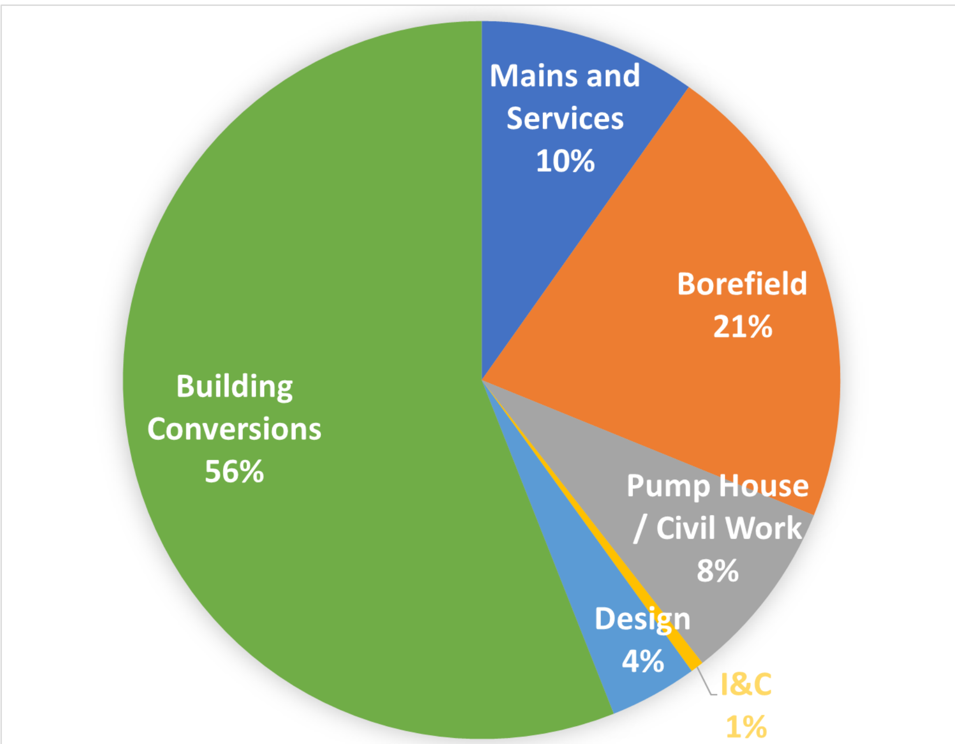
Framingham Expansion

- Expansion on existing loop
- Approximately doubling the capacity and number of customers
- Utilize existing pump house, instrumentation, and controls
- Add marginal boreholes as needed to support loads
- Vaulted pumps to control flow



Projected Expansion Costs

Projected Expansion Budget



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- Major project costs end up being the building conversion work and borefield drilling
- Overall costs expected to be about 40% lower vs original loop

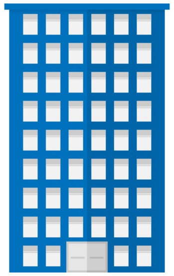
Building System Types

Single Family Home

- Forced air with ducting
- VRF with split heads (similar to air source mini-splits)
- Combination of forced air and splits

Apartment Buildings

- Corner / console units
- Stacked forced air units
- Hydronic / hot water only units (no cooling)



Commercial Buildings

- Water to water commercial system
- VRF with split heads
- Rooftop water to air units

Water to Air Heat Pump Options

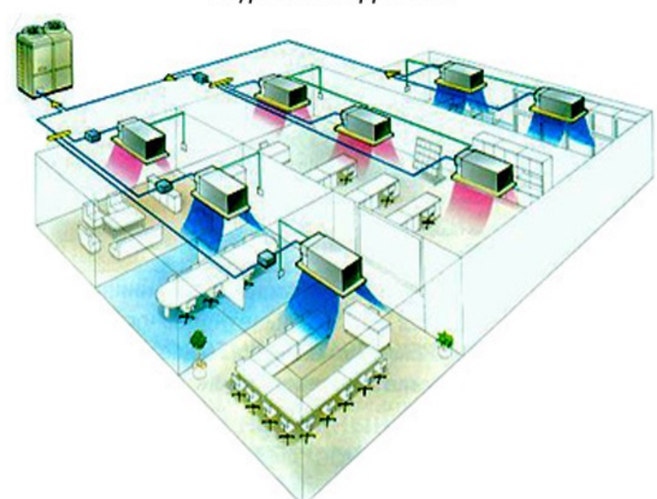
Packaged Unit

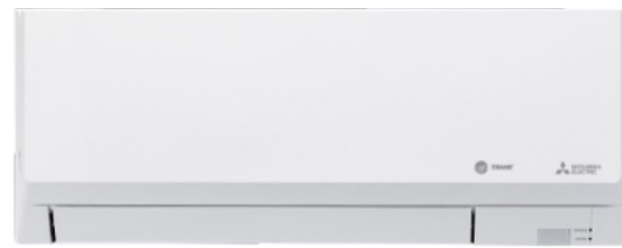
Console Unit

VRF Heat Pump Options

- Variable refrigerant flow systems allow for distributed conditioning in a building
- No ducting required, heating and cooling produced from head units
- Multiple options from wall mounted to ceiling mounted split heads

Figure 5.
A typical VRF application





System Performance in First Heating Season

System Monitoring:

SCADA with real time feedback:

Temperature

Pressure

Flow

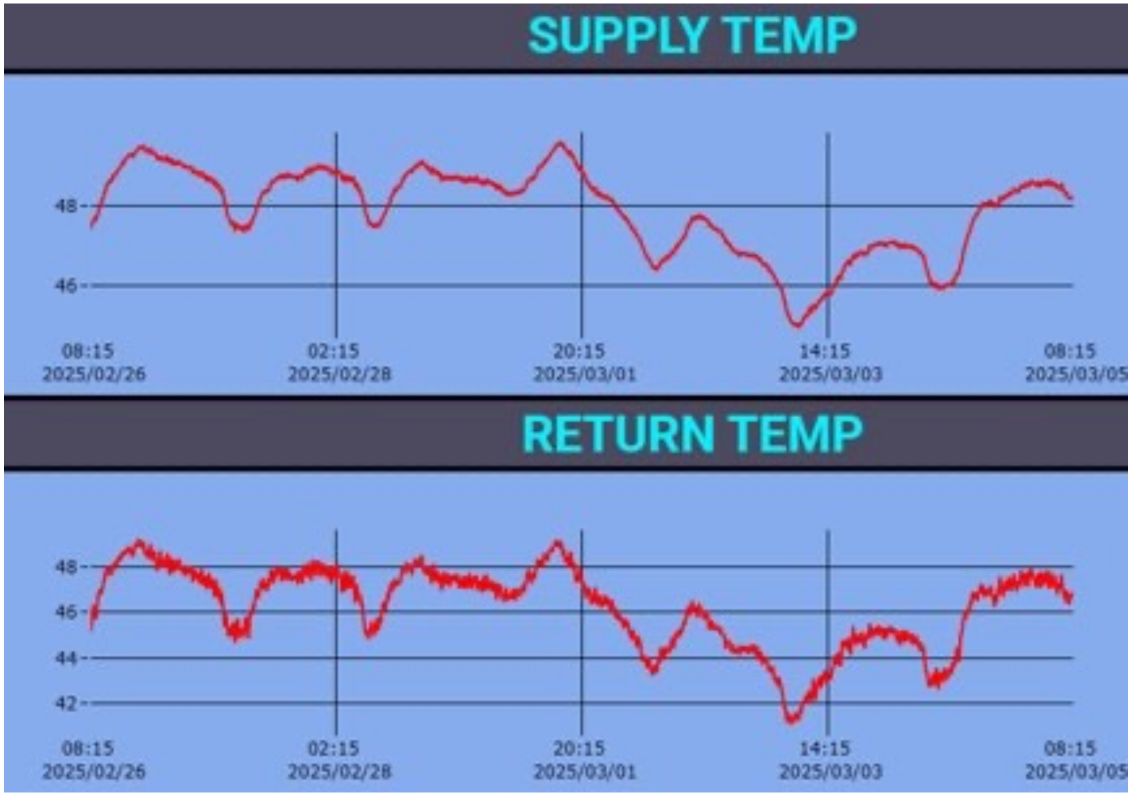
Energy usage

Impact:

Carbon Reduction

Energy Consumption

System Efficiency



Lessons Learned

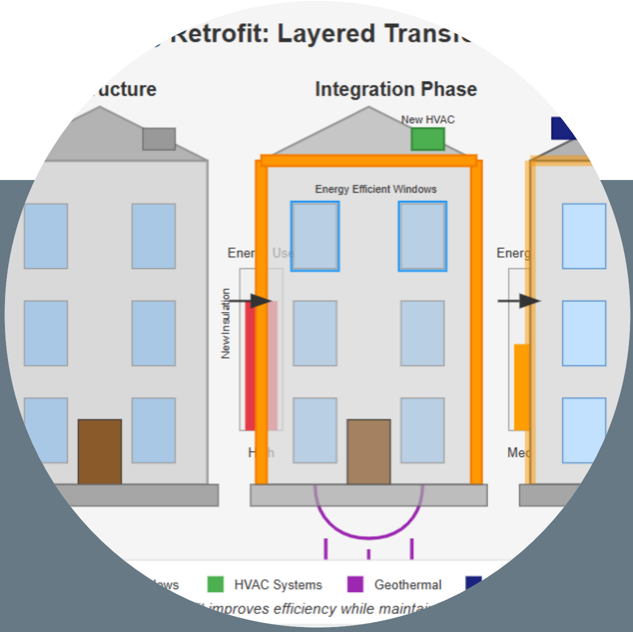
Stakeholder engagement early and often	Know your space – equipment needs, routing challenges, hazards (asbestos/lead)	Plan reviews with stakeholders at 60% design phase
Coordination of trades during construction	Maintain contingency for unanticipated field change in building renovations	Pre-commissioning procedures, standards need to be enforced in the field
Learning curve for drillers unfamiliar with local conditions	Shortage of qualified ground-source heat pump installers	Retrofit buildings cannot be standardized – even in buildings with the same unit dimensions

The Future of Utility Scale TENs

New Construction Partnership Evaluation

Regulatory Framework & Pathways

Future of Retrofits



Quiz

1. What makes network geothermal compelling at utility scale?
2. What are the data needs for effective modeling?
3. What drives construction costs initially? How does the cost ratio change in scale-up?
4. What are the limitations of building retrofits?

Questions?

Framingham Geothermal Network