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Increasing Awareness of Geoexchange in Massachusetts – Part 1 of 5

Heat pumps are heat pumps are heat pumps, right? While most people seem to picture an air-source mini-split system when they hear 'heat pump' there actually are a variety of heat pump types. These include the common mini-splits and whole house air-to-air but there are also air-to-water heat pumps and my favorite: Ground Source Heat Pumps (GSHPs). GSHPs are used in Geoexchange Systems to efficiently heat and cool buildings and can also provide hot water.

Geoexchange systems offer significant advantages for both homeowners and businesses. In Massachusetts, where weather conditions can be extreme in both winter and summer, geoexchange systems provide distinct benefits over air-source heat pumps (ASHPs). There is some technical complexity in explaining the reasons for this. I have prepared 5 separate posts to explore some of the most compelling advantages of Geoexchange/GSHPs one at a time. The individual posts are written to stand on their own so you can pick and choose the order you read them or just focus on the topic(s) that are important to you right now.

In the Series, I provide information related to:

1. Efficiency and Peak Load Advantages
2. Aesthetic Advantages in Historic Districts
3. Longer Service Life and Lifecycle Cost Advantages of GSHPs
4. Risk from Refrigerant used in GSHPs and ASHPs
5. Potential for Networked Geothermal Systems.

I hope this Series can promote discussion of building electrification using either ASHPs and GSHPs. Here is Part 1 of 5 which considers Efficiency and Peak Loads.

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Efficiency and Peak Load Advantages of Geoexchange vs. Air-Source Heat Pumps

AIR-SOURCE HEAT PUMPS: EFFICIENCY AND PERFORMANCE

Mitsubishi's Hyper-Heating Inverter (H2i) ASHPs are designed to perform efficiently in cold climates. However, even high-performance ASHPs experience a decline in heating efficiency as outdoor temperatures drop. According to data provided by Mitsubishi Electric, the COP (Coefficient of Performance) of their ASHP systems is approximately 2.2 at 5°F and can reach up to 3.5 at 47°F. As outdoor temperatures rise, the cooling efficiency is highest at around 60°F, but the COP drops significantly at outdoor temperatures exceeding 90°F, falling below 2.0, as the system must work harder to expel heat.

For example, a typical Mitsubishi Hyper-Heating unit provides 100% heating capacity down to 5°F, but at lower temperatures, the unit's capacity decreases, and the COP is reduced. This trend is common across most air-source heat pumps, even those designed for cold climates, as the heat exchange process becomes less efficient in extreme temperatures.our local presence is a significant advantage for project implementation.

GEOEXCHANGE SYSTEMS: CONSISTENT YEAR-ROUND EFFICIENCY

Geoexchange systems, such as the WaterFurnace 7 Series GSHPs, maintain a more stable and efficient operation throughout the year. Since these systems rely on the relatively constant temperature of the Earth, which remains around 50°F to 55°F at typical installation depths, their performance is not affected by fluctuating outdoor temperatures. As a result, WaterFurnace 7 Series units can achieve a COP of 3.5 to 5.0 consistently, regardless of whether it's 0°F or 100°F outside.

This stability in efficiency offers a major advantage in regions with extreme temperature swings. For instance, while an ASHP's efficiency may plummet in sub-zero weather, a GSHP will continue to provide reliable heating with high efficiency. Similarly, in hot summer months, the cooling performance of GSHPs remains steady, unlike ASHPs, which experience declining performance in extreme heat.

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IMPACT ON PEAK ENERGY LOAD

One of the most significant benefits of GSHPs compared to ASHPs is their impact on peak energy demand. During the coldest winter days or hottest summer afternoons, when heating and cooling needs are highest, ASHPs can struggle to maintain efficiency. As a result, their energy consumption spikes during these peak periods, placing additional strain on the electrical grid.

Geoexchange systems, on the other hand, maintain a consistent load on the grid, as their efficiency does not fluctuate with outdoor temperatures. This results in reduced peak energy demand, which is beneficial not only for homeowners (who may avoid peak energy pricing) but also for the utility companies, as the grid experiences fewer stress points during extreme weather events.

TEMPERATURE *(°F)*	ASHP *(COP)*	GSHP *(COP)*
0°F	1.8 - 2.2	3.5 - 4.5
30°F	3.2 - 3.7	4.0 - 5.0
60°F	4.0	4.5 - 5.0
90°F	2.0	4.0 - 4.5
100°F	1.5	4.0 - 4.5

OPERATIONAL COST COMPARISON

To estimate the operational cost for both an ASHP and GSHP in a single-family home with a peak heating load of 78,000 BTU/hr and a peak cooling load of 55,000 BTU/hr, we need to consider the system's efficiency (COP) at these peak load points. For this calculation, we will assume average utility rates for electricity in Massachusetts at approximately $0.23 per kWh.

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HEATING COST CALCULATION

The peak heating load for this home is 78,000 BTU/hr, which converts to 22.86 kW. To determine the operational cost, we calculate the energy consumption for both systems under typical winter conditions, assuming an outdoor temperature of 5°F.

For the Mitsubishi Hyper-Heating ASHP, with a COP of 2.2 at 5°F, the energy consumption required to meet the 78,000 BTU/hr demand is approximately 10.39 kW (22.86 kW ÷ 2.2). Over the course of a 24-hour period, the ASHP would consume approximately 249.36 kWh (10.39 kW x 24 hours), resulting in a daily cost of $57.35 (249.36 kWh x $0.23).

For the WaterFurnace 7 Series GSHP, with a COP of 4.0 at 5°F, the energy consumption to meet the same demand is significantly lower at 5.72 kW (22.86 kW ÷ 4.0). Over a 24-hour period, the GSHP would consume 137.28 kWh, resulting in a daily cost of $31.57 (137.28 kWh x $0.23).

COOLING COST CALCULATION

For cooling, the peak load is 55,000 BTU/hr, which converts to 16.11 kW. Assuming an outdoor temperature of 90°F, we calculate the energy consumption for both systems.

For the Mitsubishi Hyper-Heating ASHP, with a cooling COP of 2.0 at 90°F, the energy consumption required to meet the 55,000 BTU/hr demand is 8.05 kW (16.11 kW ÷ 2.0). Over a 24-hour period, the ASHP would consume approximately 193.20 kWh, resulting in a daily cost of $44.44 (193.20 kWh x $0.23).

For the WaterFurnace 7 Series GSHP, with a COP of 4.0 at 90°F, the energy consumption to meet the same demand is 4.03 kW (16.11 kW ÷ 4.0). Over a 24-hour period, the GSHP would consume 96.72 kWh, resulting in a daily cost of $22.25 (96.72kWh x $0.23).

In summary, the GSHP offers significant operational savings over the ASHP, particularly during periods of extreme heating or cooling demand. For heating, the GSHP costs approximately 45% less to operate, and for cooling, it costs about 50% less. These savings, compounded over a entire season, demonstrate the considerable financial advantages of a geoexchange system in regions with wide temperature fluctuations.

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ENERGY DEMAND AND GRID STABILITY

ASHPs are highly sensitive to outdoor air temperatures, meaning their efficiency drops significantly during periods of extreme cold (winter) or heat (summer). In Massachusetts, where winters can be harsh and summer days can reach high humidity and heat levels, the increased energy demand from ASHPs at these times can lead to spikes in grid demand.

During peak demand periods, such as the coldest winter nights or hottest summer afternoons, ASHPs would require more energy to compensate for their reduced efficiency. This places greater pressure on the grid, potentially leading to the need for more power generation capacity to handle these spikes.

GSHPs, by contrast, tap into stable underground temperatures, maintaining high efficiency year-round (typically 300-500% efficiency). This stability means GSHPs can mitigate peak load increases since they do not rely on fluctuating outdoor conditions. As more buildings adopt GSHPs, the grid would face fewer peak demand stresses, allowing for a more predictable and manageable energy load profile.

Reduced Need for Peak Power Generation

Electric grids are designed to handle peak loads—the highest possible demand periods. However, building out a grid to support these rare peak moments is highly inefficient and costly, as power plants must be built and maintained even though they only run during these peak times.

If most buildings adopt ASHPs, the need for new peak power generation capacity will rise dramatically. Utilities might need to invest in more fossil fuel-powered peaker plants, which are costly, inefficient, and run only a few hours a year.

With widespread adoption of GSHPs, however, peak loads would be significantly reduced, lowering the need for new peaker plants. This could save billions of dollars in grid build out costs, allowing utilities to focus more on renewable energy integration and less on expensive, short-use generation capacity.

Impact of GSHPs on Electrification:

If all buildings were to adopt ASHPs, the grid would face significant challenges in terms of peak load management, leading to higher costs for grid build out, more fossil fuel reliance, and the need for more extensive energy storage solutions. However, widespread adoption of GSHPs would stabilize energy demand, reduce the need for peak power generation, lower the costs associated with grid upgrades, and better support the transition to a renewable-powered grid. In this context, GSHPs offer a more sustainable and economically viable option for future grid planning.