Demonstration and Performance Monitoring of Foundation Heat Exchangers (FHX) in Low Load, High Performance Research Homes

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ACKNOWLEDGEMENT

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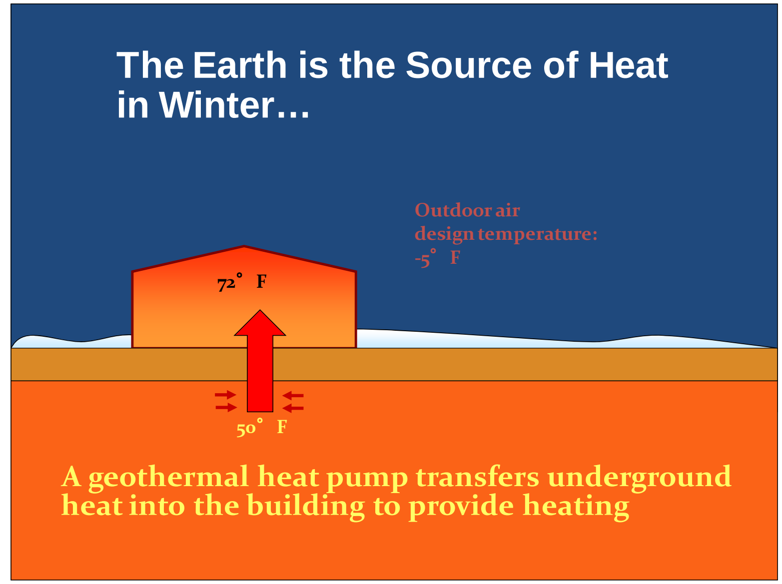
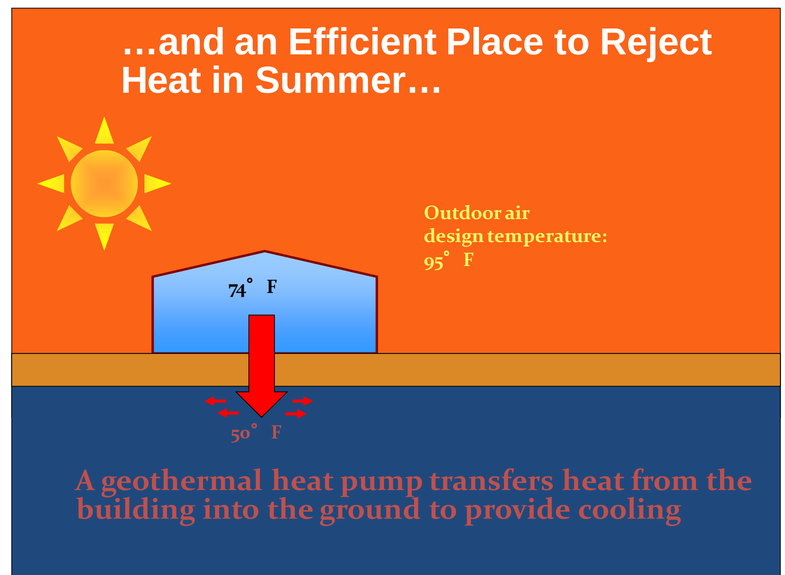
PRESENTATION OVERVIEW

- INTRODUCTION
- FIELD TEST OF THE FOUNDATION HEAT EXCHANGER (FHX) CONCEPT
- FOUNDATION HEAT EXCHANGER PERFORMANCE MEASUREMENTS
- ADDITIONAL FINDINGS AND COST COMPARISON
- SUMMARY

INTRODUCTION: Background

- **Ground Source Heat Pump Systems :**
    - One of the most energy efficient technologies for space conditioning and water heating
    - **Barrier**: Cost premium of GSHP





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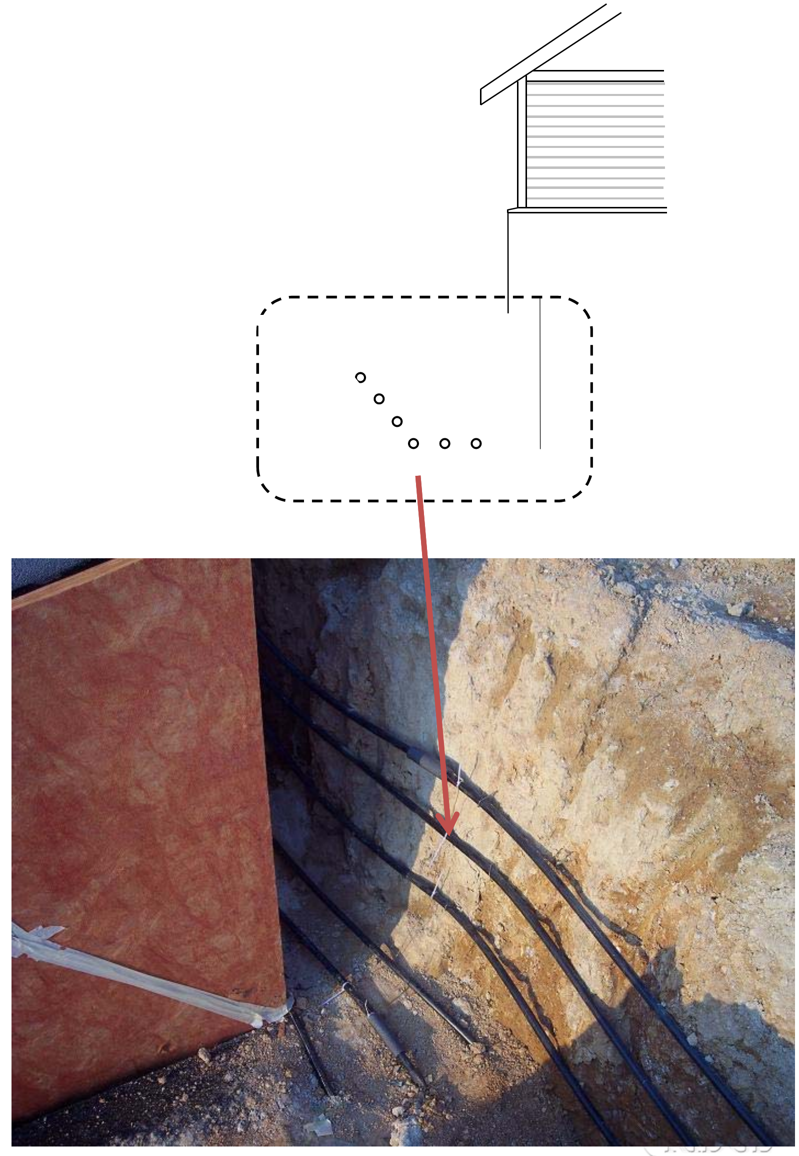
- **Foundation Heat Exchanger (FHX)**
  - Utilizing construction trench



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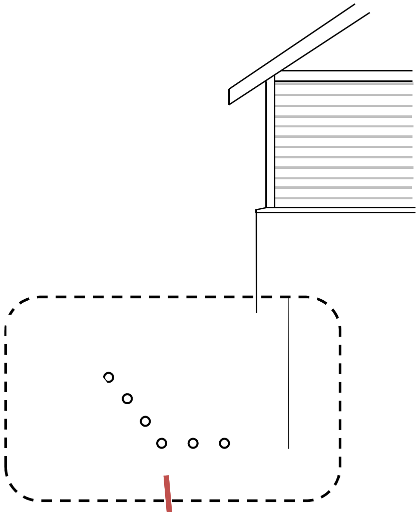
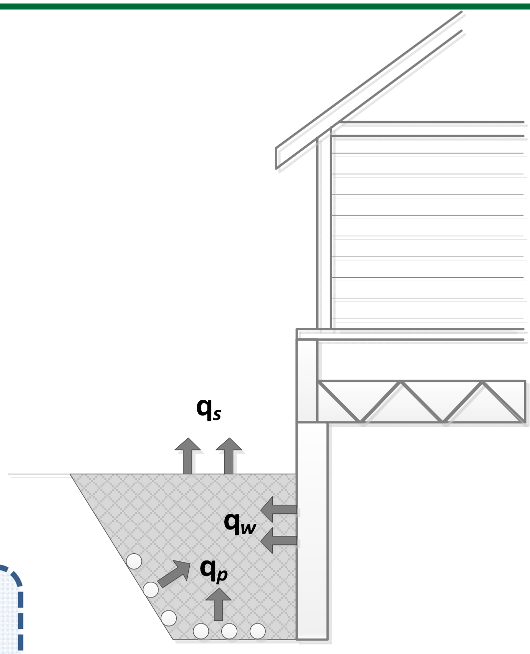
- **Foundation Heat Exchanger (FHX)**
  - Utilizing construction trench
- **Why FHX for Low-load energy efficient homes**
  - Low space conditioning loads

    ➡ Ideal for FHX implementation with minimum supplement excavation



INTRODUCTION: Research Objectives

- **Development of FHX Model and Design Tool**
  - Detailed description/results in several papers (Spitler et al. 2010, Xing et al. 2010, 2011, 2012, Spitler et al. 2010)



- **Demonstration of the FHX in full size houses (proof of concept):**
  - Design, construction and demonstration of FHX in two research houses in Oak Ridge, TN.
  - Performance monitoring results after one year of operation

FIELD TEST: Two Research Houses

- Identical 3,700 sqft floor plan
- Unoccupied houses with simulated occupancy (i.e., simulated MELs, DHW uses, and occupant's internal heat gain)
- Different envelope strategies:
  - ✓ Structural Integrated Panels (SIPs)
  - ✓ Optimal Value Framing (OVF)
- Very low air leakage and high R-values

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➨ Low space conditioning loads (i.e., **2 ton** installed vs. **4 to 5 ton** for similar houses around)

➨ Ideal for FHX implementation with minimum supplement excavation

FIELD TEST: Two Research Houses

- **Space Conditioning and DHW Systems**
  - ✓ 2 ton WAHP (space conditioning) and 1 ½ WWHP (DHW) connected to FHX/HGHX

House 1 (SIP)

House 1 (OVF)

FIELD TEST: FHX Design

Loop configuration:
¾ inch diameter high-density polyethylene (HDPE) pipes (three fluid circuits – out and back)

Residential Load Calculation:
Manual J and S

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Conventional HGHX Loop Design Tool
Max/Min EFT (F): 95 and 30F

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Required Length of the Trench (ft)
SIP House: 300 ft
OVF House: 360 ft

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Required Length of the Trench (ft)
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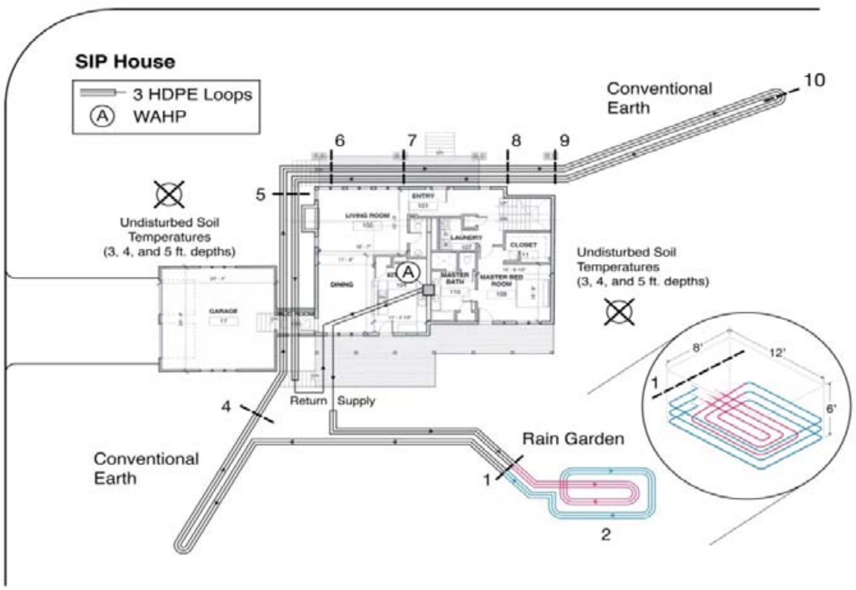
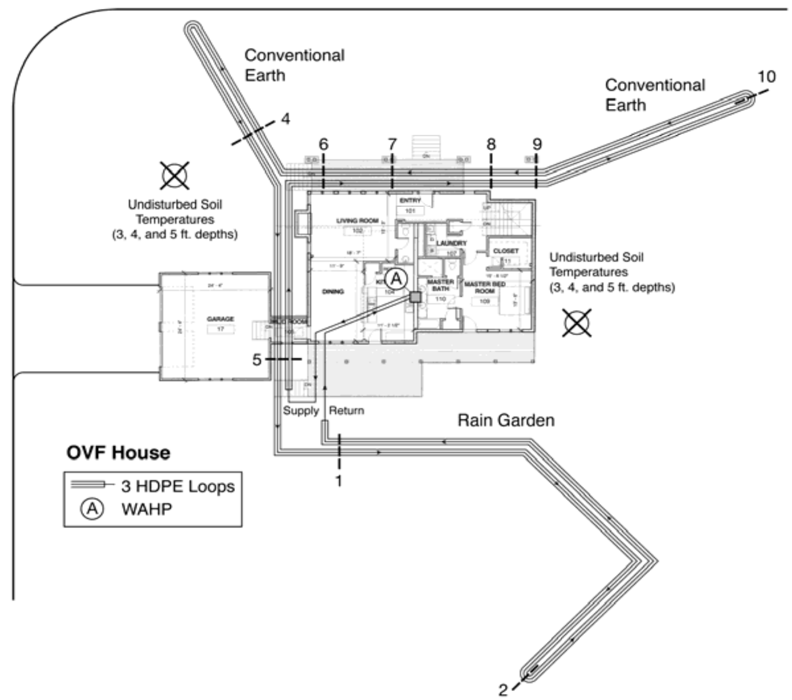
Construction Excavation (ft)
SIP house: 180 ft (60% of total)
OVF house: 180 ft (50% of total)

Additional Excavation (ft)

FIELD TEST: FHX Design



Layout of FHX and HGHX at House 1 (SIP) (Numbers show measurement points)



Layout of FHX and HGHX at House 2 (OVF) (Numbers show measurement points)

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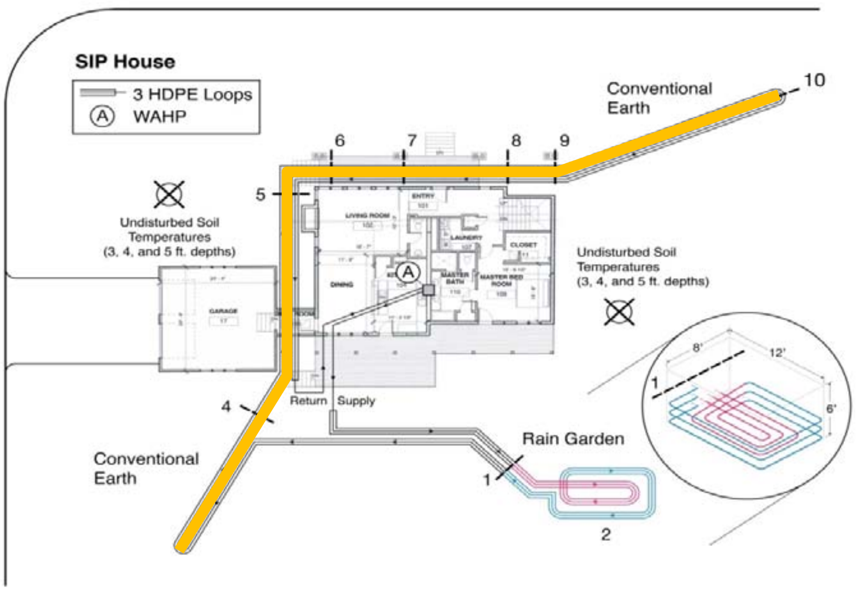

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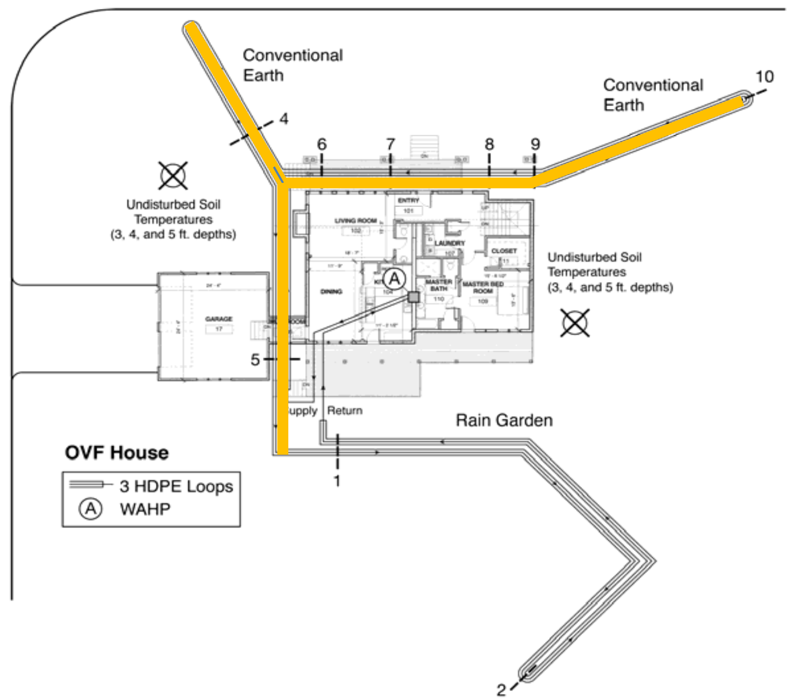
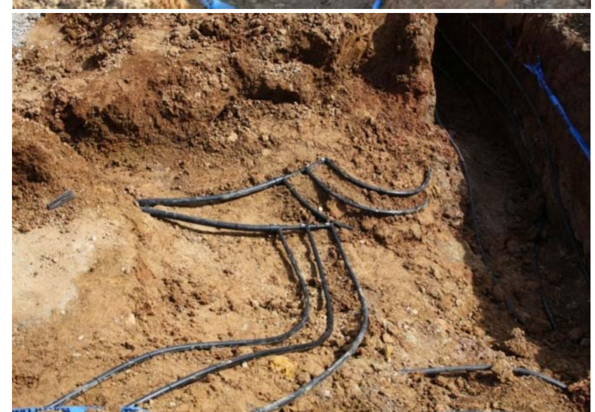


Layout of FHX and HGHX at House 2 (OVF) (Numbers show measurement points)

FIELD TEST: Construction and Measurement Setup

- Purpose: Model validation and FHX energy performance analysis



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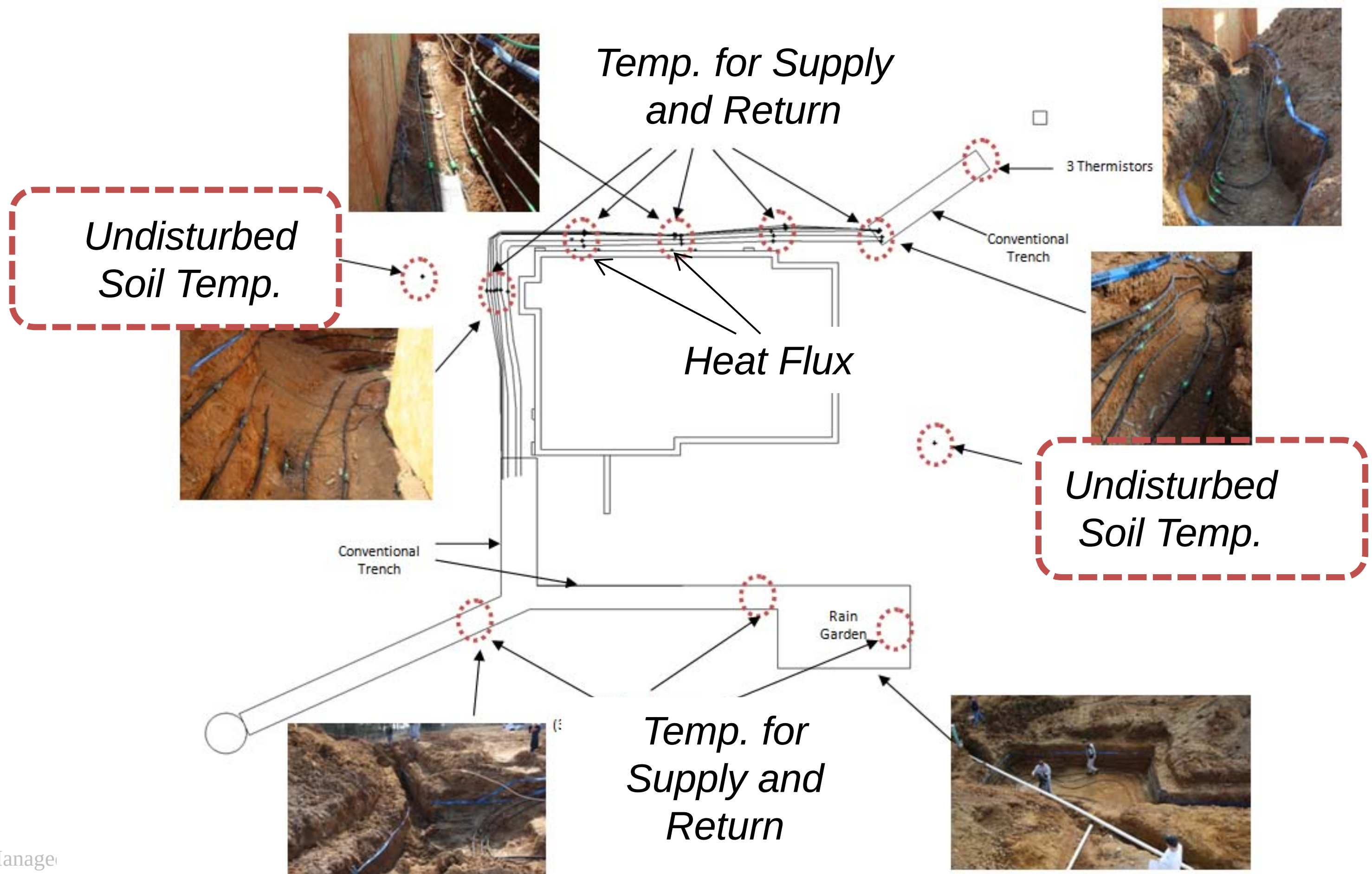

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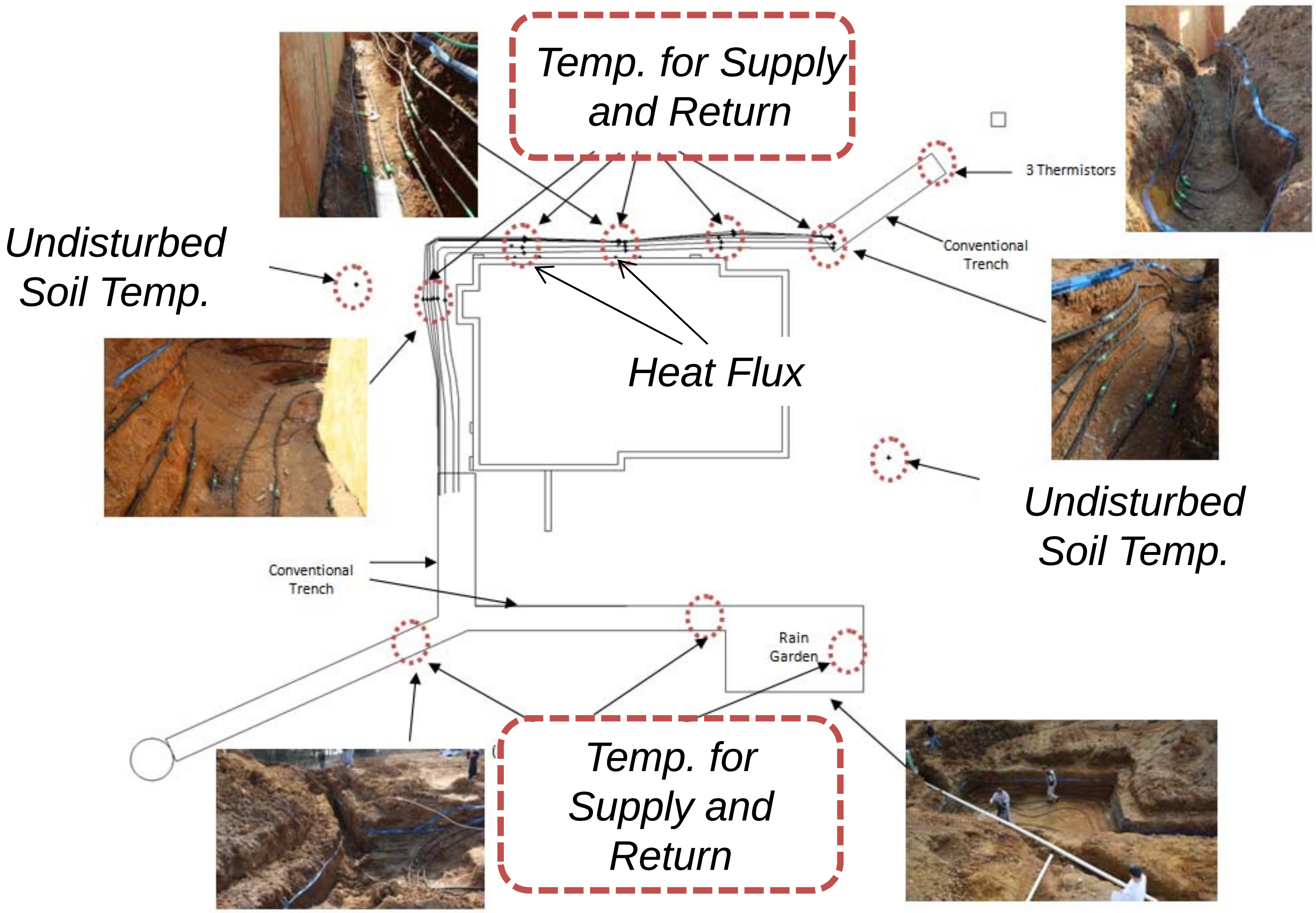

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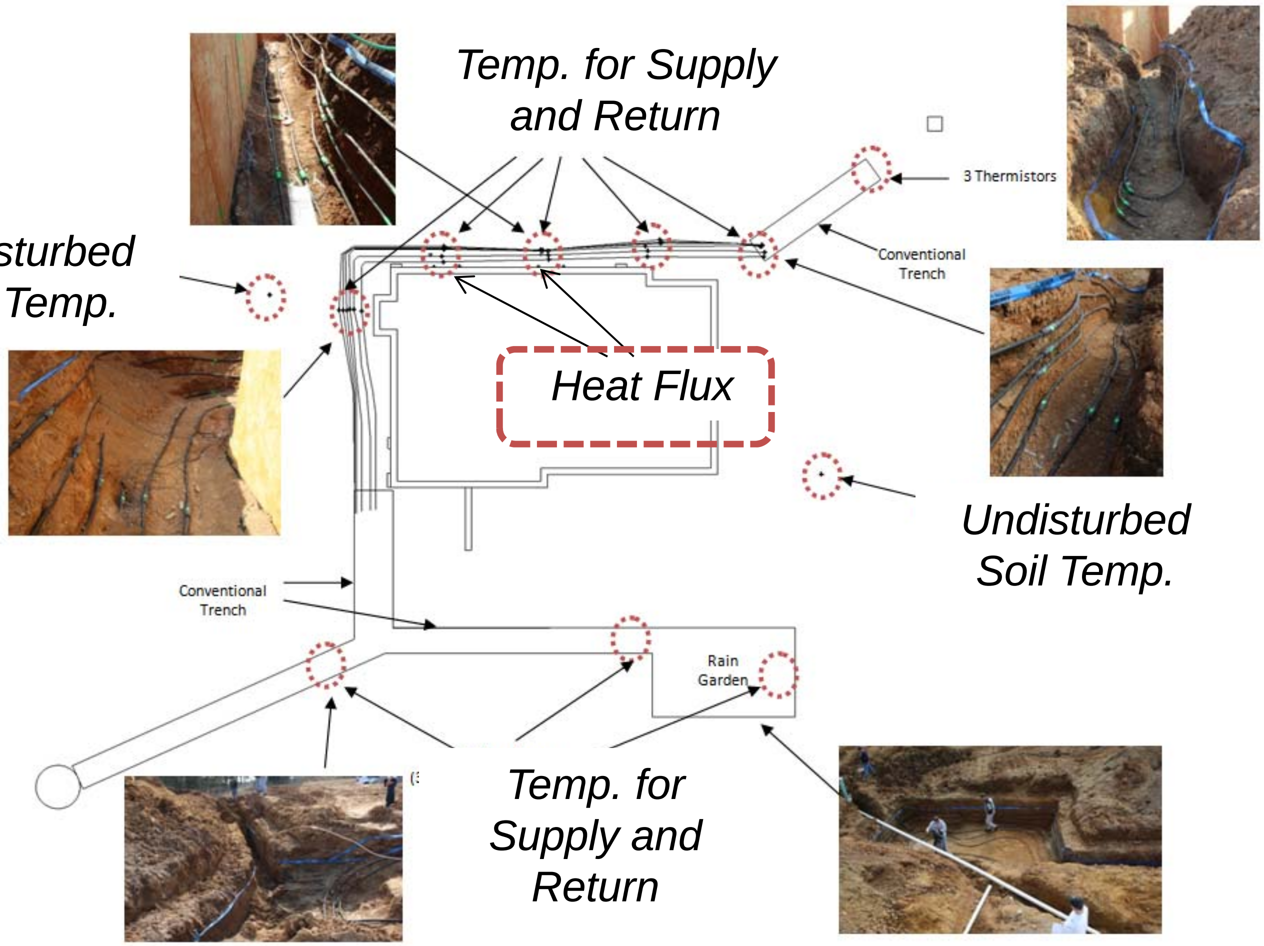

RESULTS: Performance measurements (Year 1)

	House 1 (SIP)	House 2 (OVF)
Cooling/Heating Thermostat	76F/71F (Maintained)	76F/71F (Maintained)
Supplemental electric resistance heating	None	66kWh
Annual Average Cooling System EER *(including pumping)*	14.3	14.0
Annual Average Heating System COP *(including pumping)*	3.6	3.6
Average DHW COP	3.1	2.6

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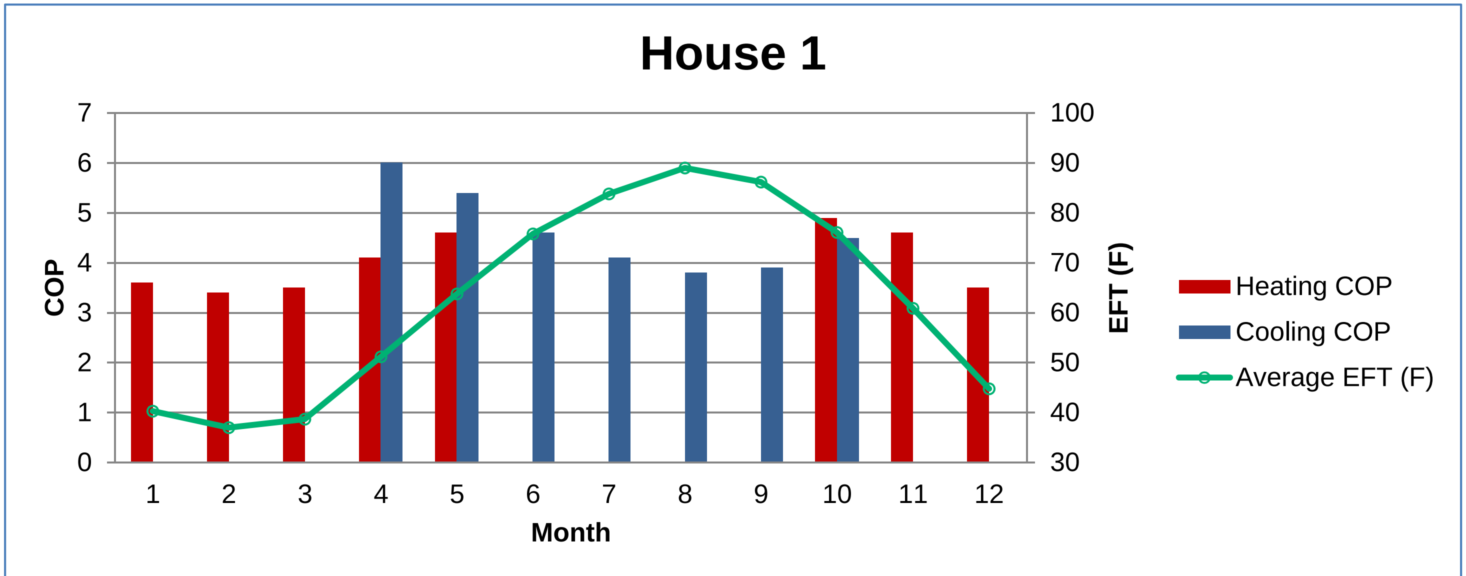

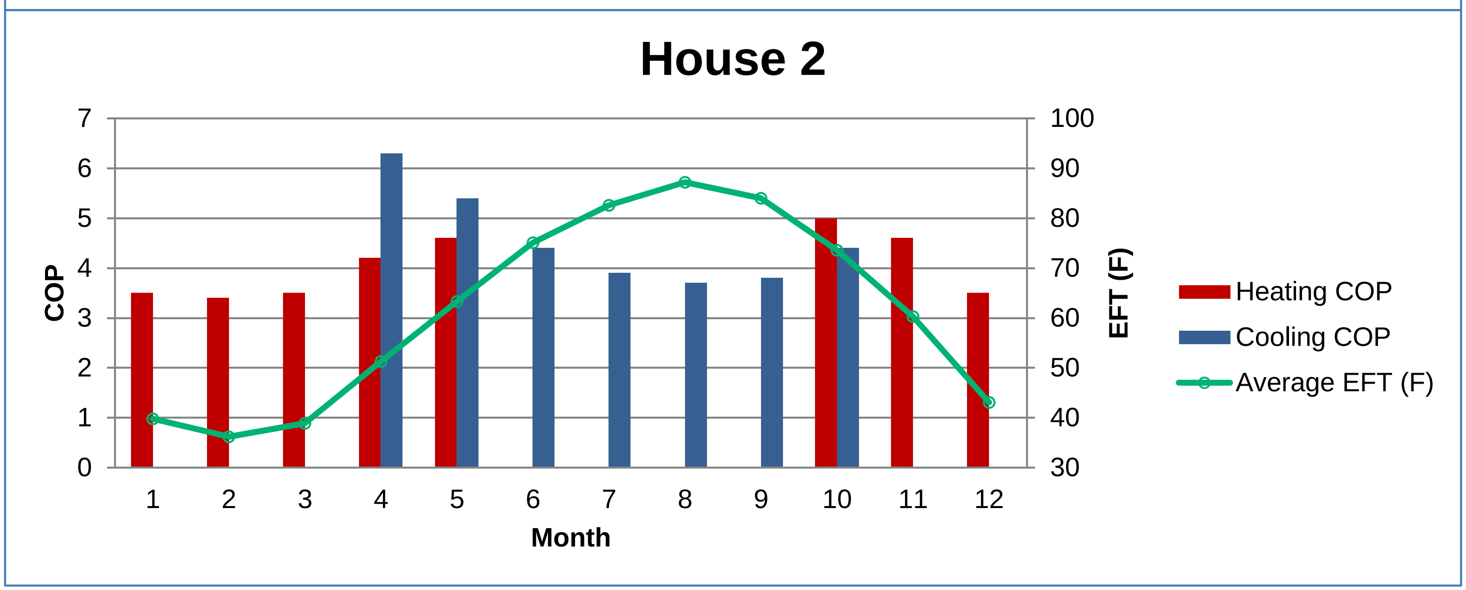

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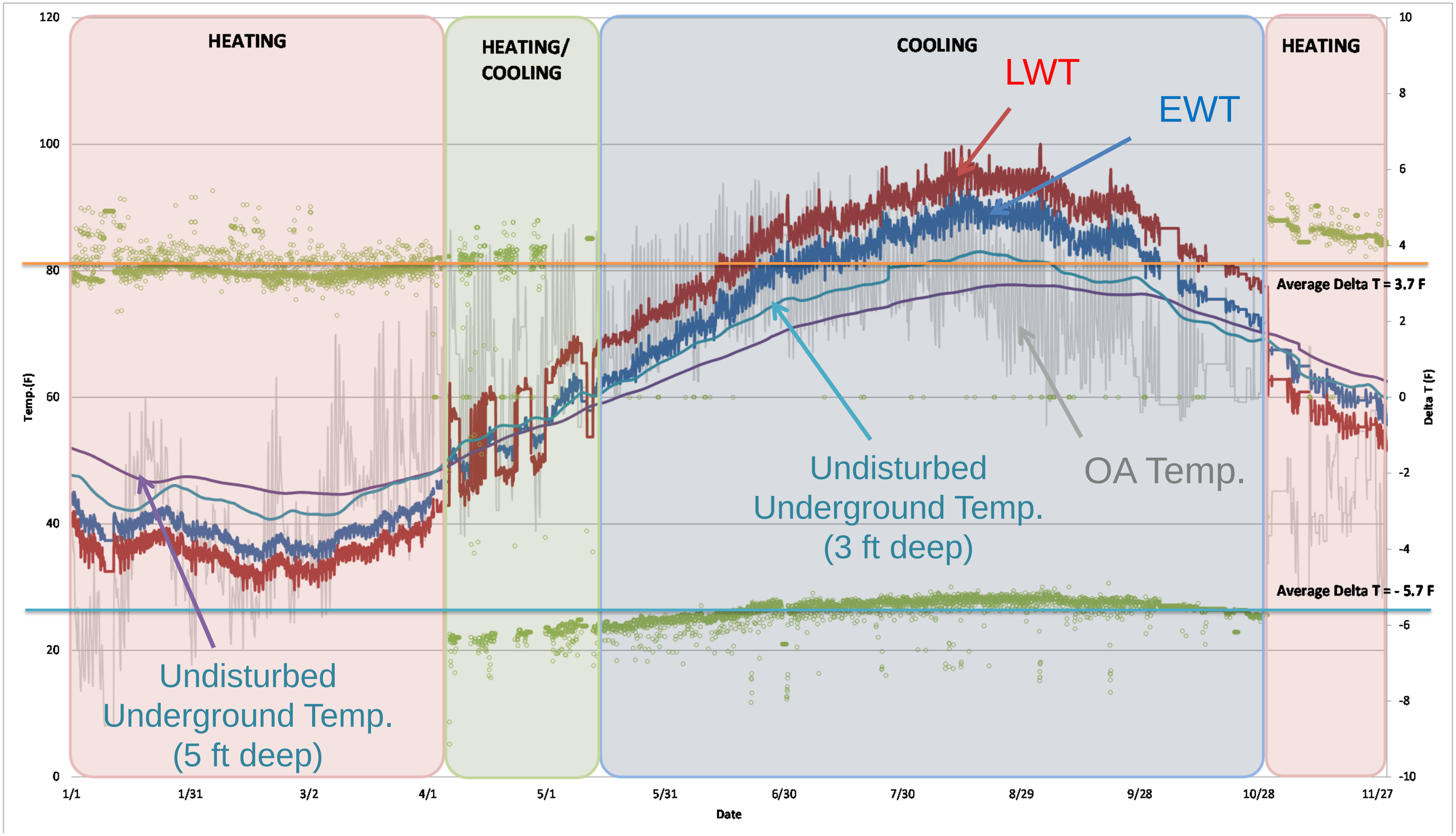
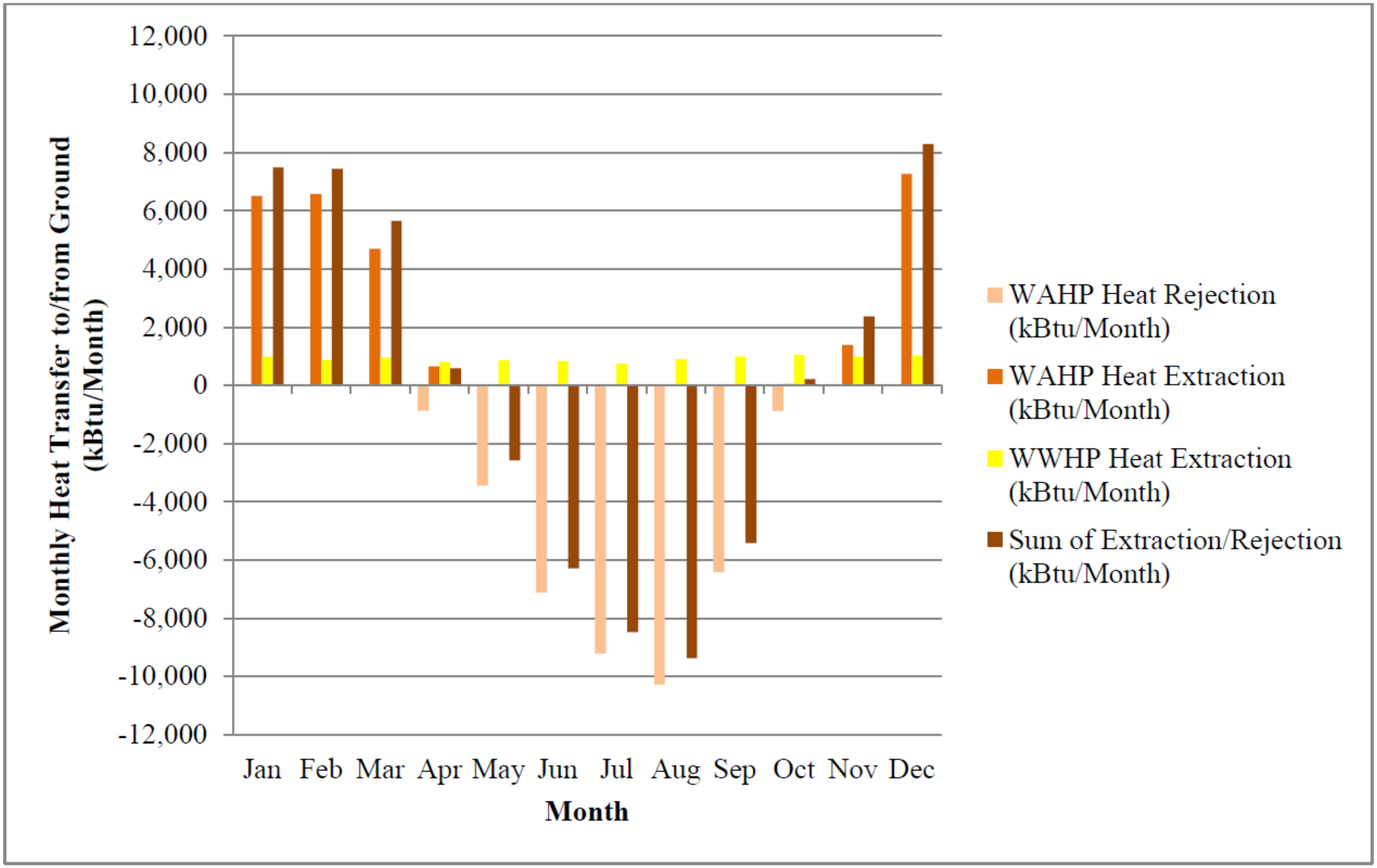


RESULTS: Performance measurements (Year 1)

- FHX measurements
  - Annual maximum and minimum EFTs (within design range)
    - ✓ House 1: **93.2 F**, and **33.4F**, respectively.
    - ✓ House 2: **90.3 F**, and **33.7F**, respectively.
  - Average Delta T for cooling and heating
    - ✓ Cooling: - 5.7F
    - ✓ Heating: 3.7F
  - Annual heat transfer between WAHP/WWHP and Ground
    - ✓ Near zero (well balanced) ➡ No significant long term operation penalty expected.

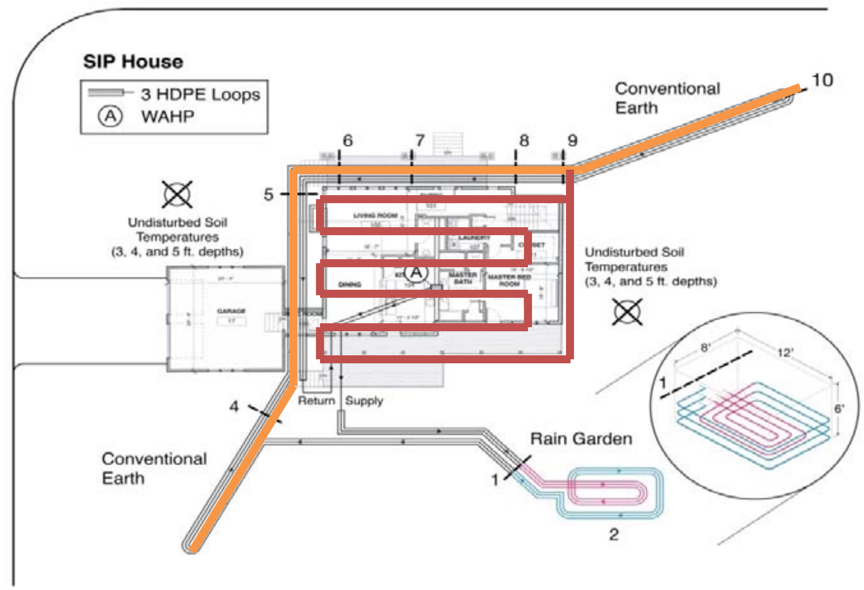
RESULTS: Heat Transfer (House 1) (Year 1)



Additional Findings and Cost Comparison

- **50% to 60%** of the total ground loop was installed in existing construction excavation or utility trenches → *extra trench excavation needed*

- **100%** of the total ground loop could be installed only using existing construction excavation



- **Cost Comparison (GHX portion)**

Type GHX	Vertical Loop	Horizontal Loop	FHX
Installation Cost	\$3,000/ton	\$2,250/ton	\$1,000/ton

Summary/Conclusion

- GSHP and Market barrier
- Foundation Heat Exchanger Concept – cost reduction & performance
- Demonstration and performance measurements of FHX in two side-by-side, three-level, occupancy simulated research houses
- 50% to 60% of the total ground loop could be installed in existing construction excavation or utility trenches for the study houses
- 100% of the total ground loop could be installed only using existing construction excavation if under the slab excavation would be used for GHX installation

Summary (continued)

	House 1 (SIP)	House 2 (OVF)
Cooling/Heating Thermostat	76F/71F (Maintained)	76F/71F (Maintained)
Supplemental electric resistance heating	None	66kWh
Average Cooling System COP *(including pumping)*	4.2	4.1
Average Heating System COP *(including pumping)*	3.6	3.6
Average DHW COP	3.1	2.6

Summary (continued)

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Thanks,

Questions and Comments,

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FIELD TEST: Two Research Houses (Continued)

Envelope component	House 1 Structural Insulated Panel (SIP) Strategy	House 2 Optimal Value Framing (OVF) Strategy
Roof	IRR standing seam metal	IRR standing seam metal
Roof deck	SIPs	Foil facing on phenolic foam
Roof Deck Ventilation	Open at eave and ridge above sheathing	Open at soffitt and ridge below sheathing
Attic	R-35 Cathedral (SIPs 10 in.)	R-50 Cathedral (aged phenolic) 24 in. O.C.
Wall	R-21 SIPs (6 in. thick)	R-21 2x6 wood frame, 24 in. centers with ½ in. OSB
Wall cavity	SIP (EPS)	Flash & batt (½ in. foam with R-16 batt)
Window	triple pane, third pane removable	triple pane, third pane removable
Floor	20 in. truss between basement & first floor with installed ductwork and 18 in. truss between first and second floor.	20 in. truss between basement & first floor with installed ductwork.
Foundation	Basement	Basement
Weather-resistive barrier	Applied	Applied
Foundation wall above grade	12 in. poured concrete with exterior 2 3/8 in. fiberglass drainage board insulation; stone facade	10 in. poured concrete with exterior 2 3/8 in. fiberglass drainage board insulation; stone facade
Foundation wall below grade	12 in. poured concrete with exterior 2 3/8 in. fiberglass drainage board	10 in. poured concrete with exterior 2 3/8 in. fiberglass drainage board