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Geothermal Tools For Success

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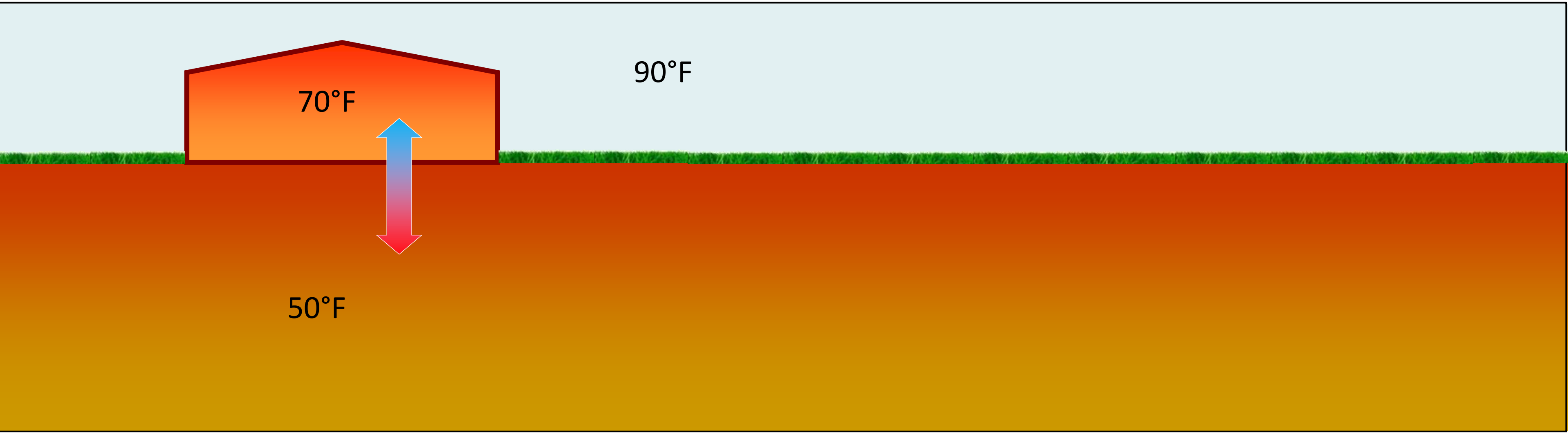
Outline

1. Pre-feasibility tool
2. Predictive BTU meter
3. COP meter

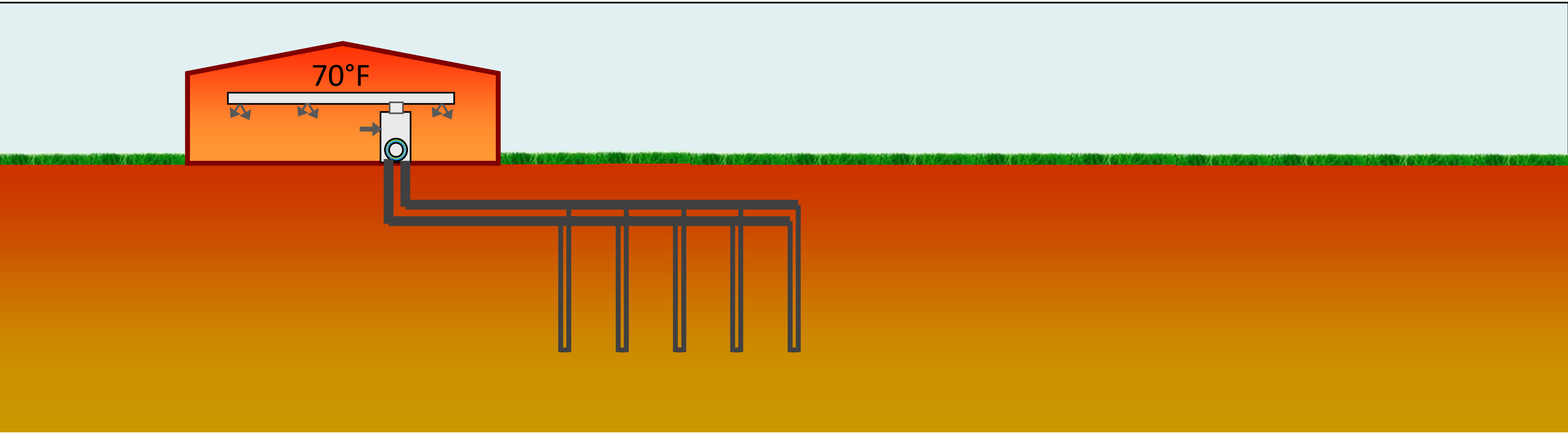
Earth Energy Resource

- Constant earth temperature
- Variable outdoor air temperature



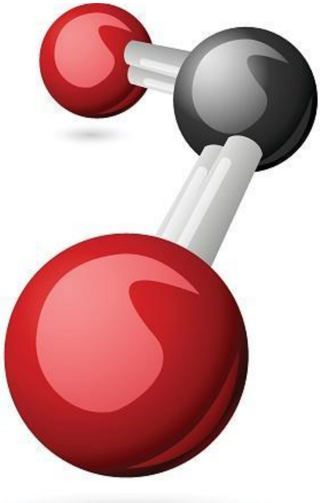
Earth Energy Resource

- Plastic pipe transfers heat to volume of earth
- Heat exchange fluid is pumped through the pipe
- Pipe is connected to a heat pump



Geothermal Perceptions

- Perceived high cost
- Perceived risk
- Environmental benefit



Rules of Thumb

- Rules of thumb often used to provide quick answers to clients
- Rules of thumb are dangerous - cost and design of a GHX is sensitive to many factors

Peak Loads vs. Total Loads

- Peak cooling loads for 3 buildings are identical – 480 kBtu/hr (40 tons)
- Peak heating loads are identical – 385 kBtu/hr

Peak Loads vs. Total Loads

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- Different occupancy creates different annual total heating and cooling loads
- Heating / cooling ratio impacts sustainability and size of GHX

	Church					Retail					Apartment			
	Clg kBtu	Clg kBtu/hr	Htg kBtu	Htg kBtu/hr		Clg kBtu	Clg kBtu/hr	Htg kBtu	Htg kBtu/hr		Clg kBtu	Clg kBtu/hr	Htg kBtu	Htg kBtu/hr
Jan	3820	8	189734	**385**	Jan	19906	93	89734	**385**	Jan	5560	25	159734	**385**
Feb	6202	23	135120	366	Feb	28202	110	65120	346	Feb	7840	83	112120	360
Mar	12177	76	81304	312	Mar	30177	215	41304	240	Mar	14177	185	71304	305
Apr	16800	216	36614	170	Apr	40866	285	16614	110	Apr	28866	260	30614	155
May	24640	367	11152	65	May	53946	396	3152	35	May	43946	329	11152	60
Jun	46285	446	3180	5	Jun	82094	446	180	0	Jun	72094	423	8545	45
Jul	52680	**480**	886	0	Jul	102358	**480**	0	0	Jul	92358	**480**	7650	43
Aug	49068	465	1725	0	Aug	102393	439	125	0	Aug	78393	447	7550	45
Sep	38560	314	5479	53	Sep	89245	360	2379	26	Sep	59450	360	8479	53
Oct	13821	121	24702	137	Oct	63821	223	9702	128	Oct	19821	169	18702	132
Nov	7571	62	98784	298	Nov	41571	135	36784	251	Nov	8690	79	66784	269
Dec	4884	10	176775	348	Dec	27884	102	76775	331	Dec	6570	22	126775	340
	276508	480	765455	385		682463	480	341869	385		437765	480	629409	385
	Annual Cooling / Heating Ratio:			**2.8 to 1**		Annual Cooling / Heating Ratio:			**2.0 to 1**		Annual Cooling / Heating Ratio:			**0.7 to 1**

Peak Loads vs. Total Loads

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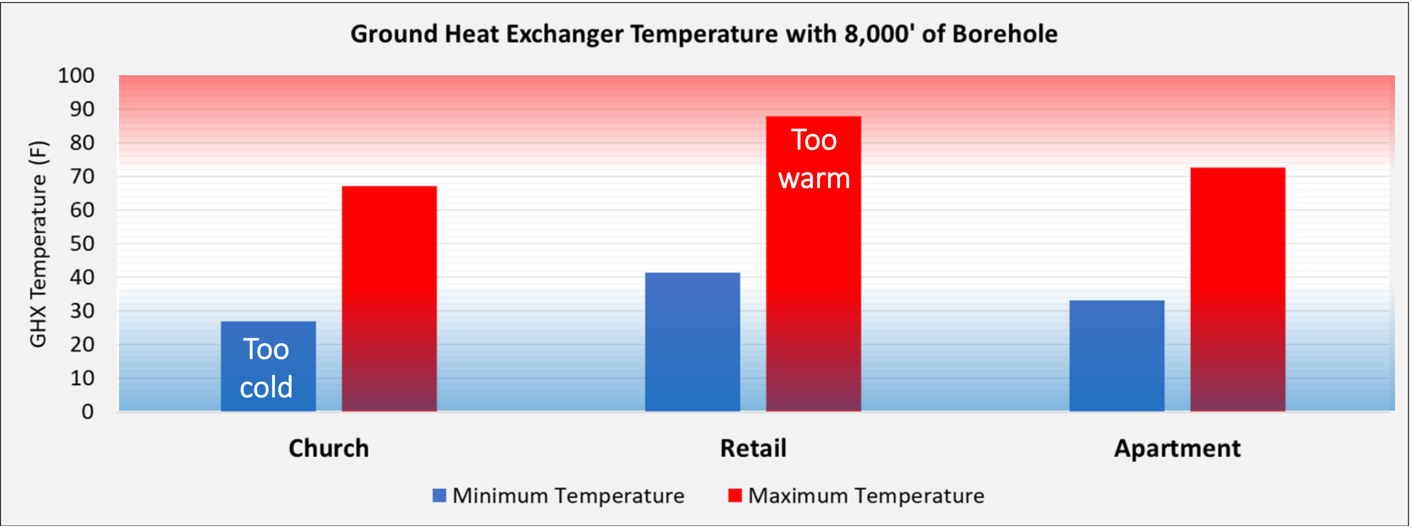
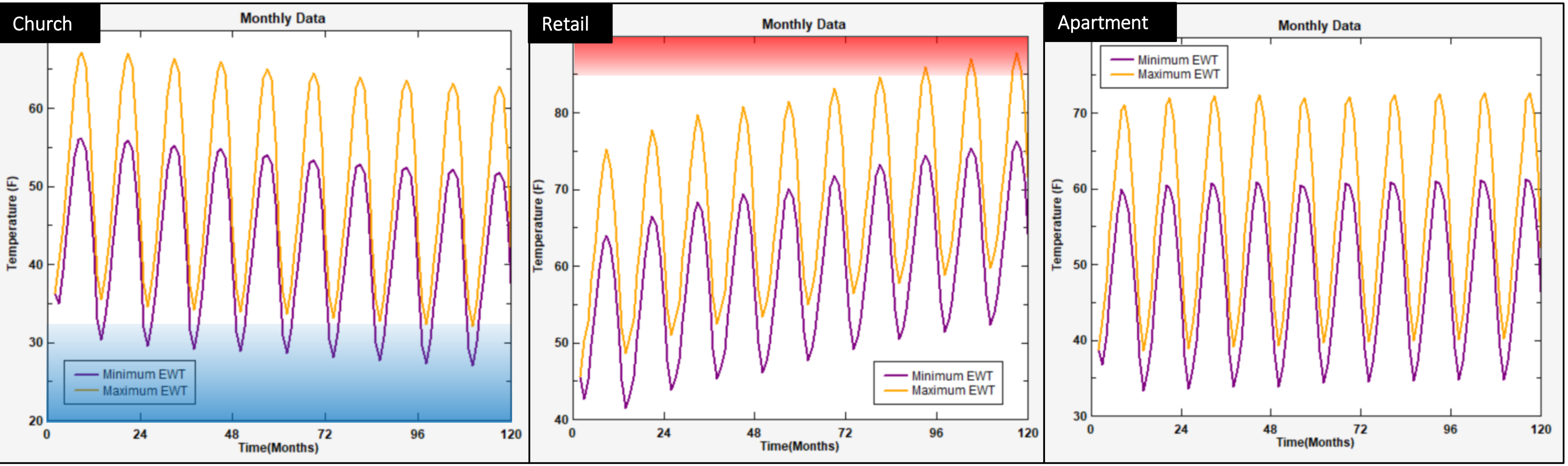
- Rules of thumb suggests these buildings need 8,000’ of borehole
- Max / min temperatures should be 30-35°F / 85-90°F for efficient heat pump operation
- Potential for heat pumps to quit working



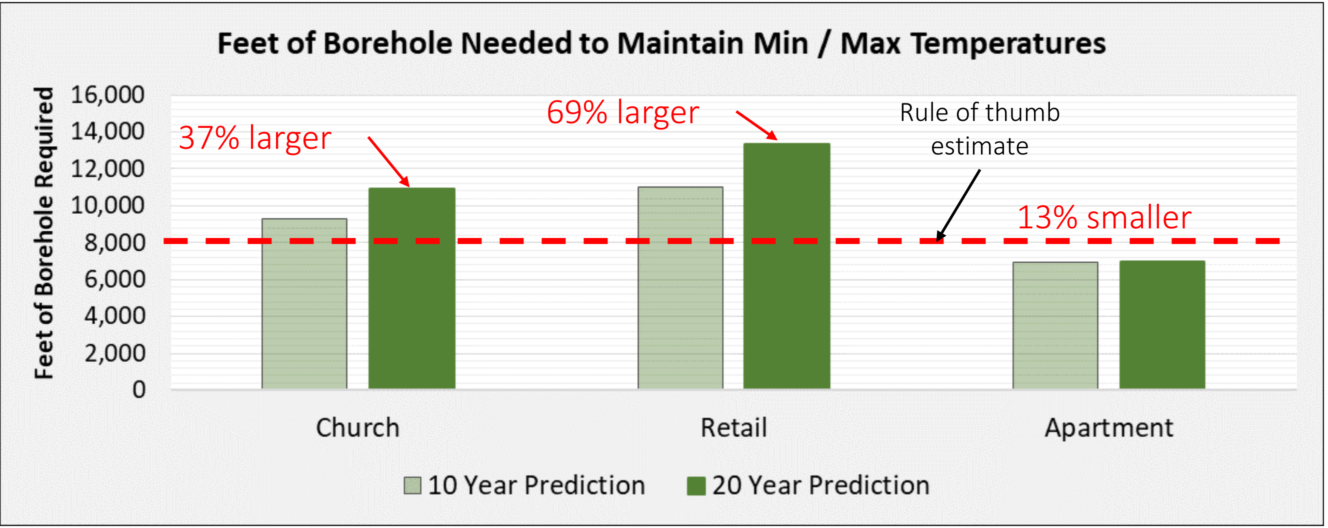
Peak Loads vs. Total Loads

- After 10 years GHX temperature for church and retail store fall outside efficient operating parameters
- Balanced loads of apartment building maintains efficient operating temperatures over time



Challenging the "Rules of Thumb"

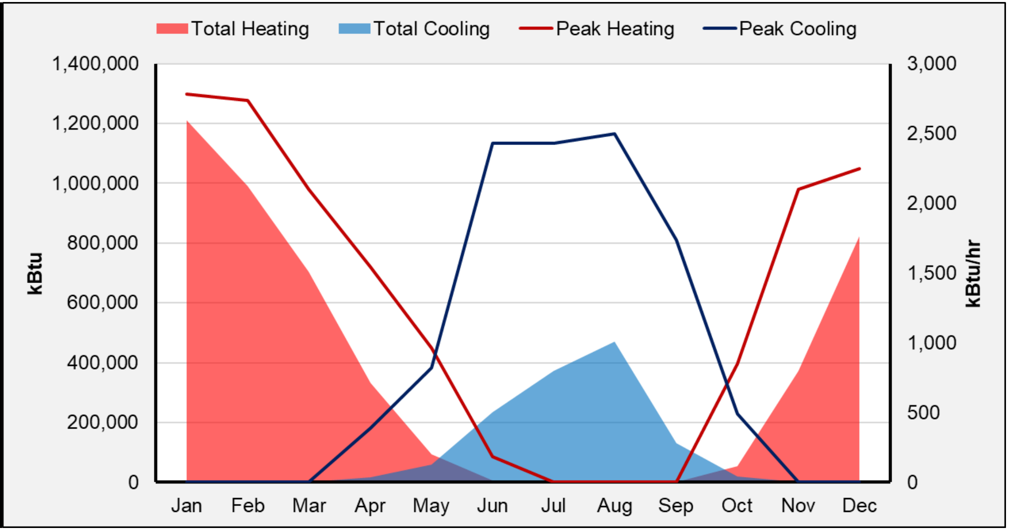
- Rules of thumb can result in projects that either:
  - Fail because of long term temperature degradation
  - Too expensive to build



Energy Models

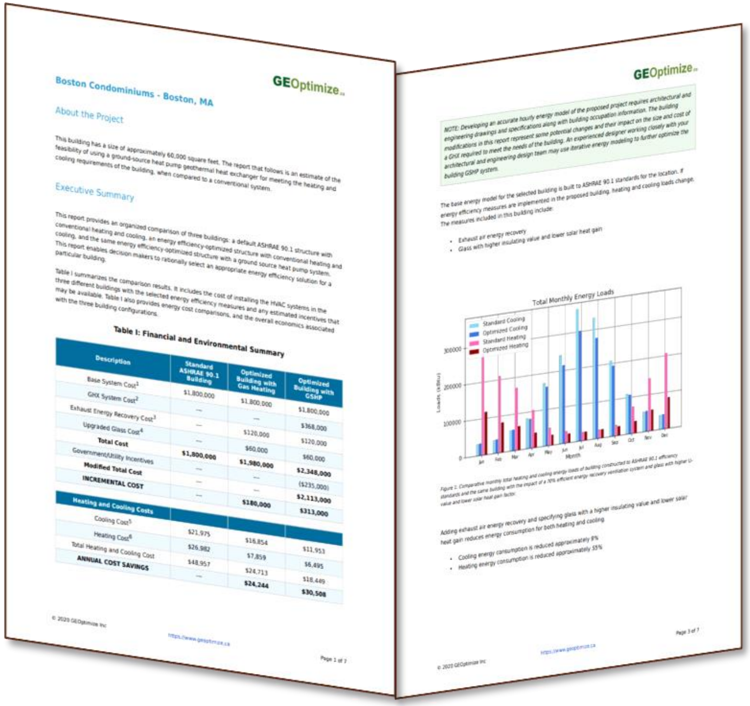
- Energy models are more accurate than rules of thumb but they can be:
  - Time intensive = expensive
  - Unique experience required

	Geo Cooling		Geo Heating	
	kBtu	kBtu/hr	kBtu	kBtu/hr
Jan	-	-	1,210,098	2,781
Feb	-	-	989,513	2,736
Mar	-	-	703,856	2,099
Apr	17,421	390	331,263	1,543
May	59,832	822	92,418	964
Jun	232,996	2,429	7,009	186
Jul	372,543	2,430	-	-
Aug	469,345	2,498	-	-
Sep	130,447	1,738	-	-
Oct	18,027	488	52,722	849
Nov	-	-	373,289	2,101
Dec	-	-	822,038	2,250
	1,300,612	2,498	4,582,206	2,781
	Tons	208	Tons	232
	EFLH	521	EFLH	1,648



ProFease

- Online web-based geothermal pre-feasibility tool
- Backed by a library of prototypical energy models
- Uses industry standard GLD ground heat exchanger sizing calculations
- Generate custom made reports to compare geothermal to a conventional system
- Can include incentives for geothermal and financial calculations including NPV, IRR, & simple payback



Boston Condominiums - Boston, MA

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About the Project

This building has a size of approximately 60,000 square feet. The report that follows is an estimate of the feasibility of using a ground-source heat pump geothermal heat exchanger for meeting the heating and cooling requirements of the building, when compared to a conventional system.

Executive Summary

This report provides an organized comparison of three buildings: a default ASHRAE 90.1 structure with conventional heating and cooling, an energy efficiency-optimized structure with conventional heating and cooling, and the same energy efficiency-optimized structure with a ground source heat pump system. This report enables decision makers to rationally select an appropriate energy efficiency solution for a particular building.

Table I summarizes the comparison results. It includes the cost of installing the HVAC systems in the three different buildings with the selected energy efficiency measures and any estimated incentives that may be available. Table I also provides energy cost comparisons, and the overall economics associated with the three building configurations.

Table I: Financial and Environmental Summary

Description	Standard ASHRAE 90.1 Building	Optimized Building with Gas Heating	Optimized Building with GSHP
Base System Cost[1]	$1,800,000	$1,800,000	$1,800,000
GHX System Cost[2]	—	—	$368,000
Exhaust Energy Recovery Cost[3]	—	$120,000	$120,000
Upgraded Glass Cost[4]	—	$60,000	$60,000
Total Cost	**$1,800,000**	**$1,980,000**	**$2,348,000**
Government/Utility Incentives	—	—	($235,000)
Modified Total Cost	—	—	**$2,113,000**
INCREMENTAL COST	—	**$180,000**	**$313,000**
Heating and Cooling Costs			
Cooling Cost[5]	$21,975	$16,854	$11,953
Heating Cost[6]	$26,982	$7,859	$6,495
Total Heating and Cooling Cost	$48,957	$24,713	$18,449
ANNUAL COST SAVINGS	—	**$24,244**	**$30,508**

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NOTE: Developing an accurate hourly energy model of the proposed project requires architectural and engineering drawings and specifications along with building occupation information. The building modifications in this report represent some potential changes and their impact on the size and cost of a GHX required to meet the needs of the building. An experienced designer working closely with your architectural and engineering design team may use iterative energy modeling to further optimize the building GSHP system.

The base energy model for the selected building is built to ASHRAE 90.1 standards for the location. If energy efficiency measures are implemented in the proposed building, heating and cooling loads change. The measures included in this building include:

- Exhaust air energy recovery
- Glass with higher insulating value and lower solar heat gain

Adding exhaust air energy recovery and specifying glass with a higher insulating value and lower solar heat gain reduces energy consumption for both heating and cooling.

- Cooling energy consumption is reduced approximately 9%
- Heating energy consumption is reduced approximately 55%

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Large Energy Model Database

- Current weather locations include:
  - Bemidji, MN
  - Crookston, MN
  - Fergus Falls, MN
  - Minneapolis, MN
  - Morris, MN
  - Bismarck, ND
  - Devils Lake, ND
  - Jamestown, ND
  - Milbank, SD
  - Sioux Falls, SD

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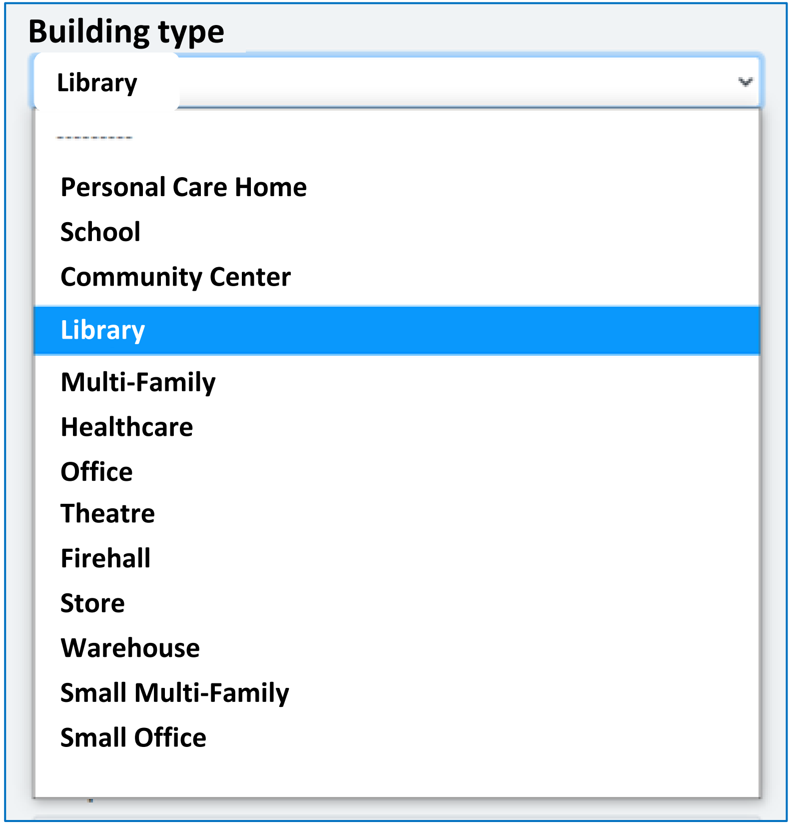
Typical Building Types

- Selected building can be scaled to match square footage of proposed building
- Each building type includes four different energy model iterations:
  - Standard building – ASHRAE 90.1
  - Add energy recovery ventilation
  - Upgraded glass
  - ERV and upgraded glass
- Some buildings include domestic hot water and refrigeration loads



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Custom Reports

- Customized report is automatically generated in ProFease
- Report customized with:
  - Company logo
  - Customized introductory section
  - Customized conclusion
  - Economics to meet client's requirements

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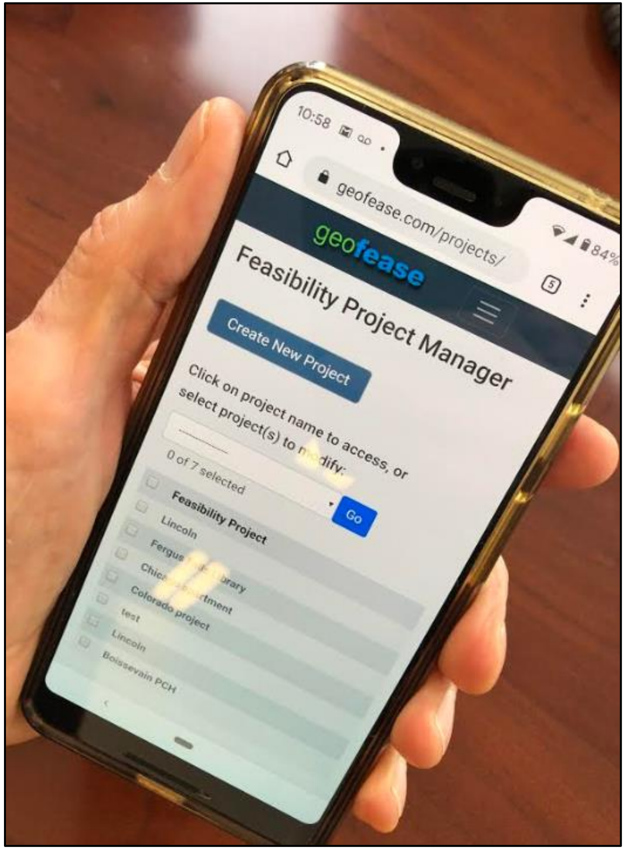
Online Feasibility Tool

- ProFease reports can be run on computer, tablet or phone
- ProFease can be run in 10-15 minutes
- Customized 6-page report
- PDF summary report can be emailed to client in minutes
- Reports are saved online until deleted



Q/A

Building Energy Modelling

- Envelope Conduction
  - Heat is conducted through all surfaces exposed to the outdoor air temperature
  - The amount of heat transferred is directly proportional to the ΔT between the indoor & outdoor air temperatures

Building Energy Modelling

- Internal heat gains
  - Occupants, lights and electrical equipment emits heat into the space
  - Building use affects the amount of heat contributed by internal gains

Building Energy Modelling

- Solar Gains
  - Solar heat is transferred to the building through windows
  - Amount of solar heat is affected by window to wall ratio and solar heat gain coefficient (SHGC) of windows
  - Affected by internal and external shading devices

Building Energy Modelling

- Ventilation
  - Heating or cooling is required to condition fresh outdoor air
  - Ventilation rate is variable based on building type
  - Ventilation heating or cooling is highly dependent on climate

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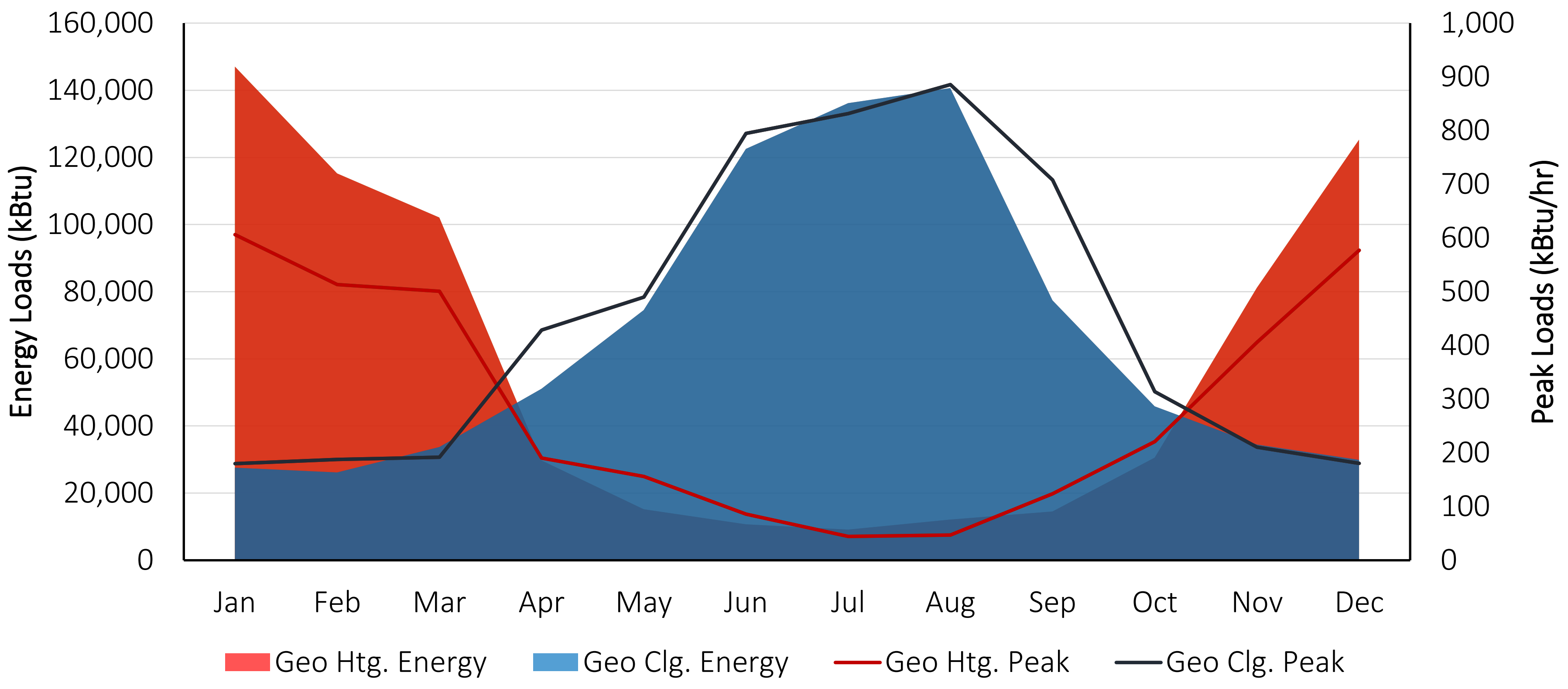
Building Energy Modelling

	A	B	C	D	E	F
1	Day Of Yr	Date/Time	Heating delivered	Cooling delivered	Heating delivered	Cooling delivered
2			Btu/h	Btu/h	kW	kW
3	1	1/1/2023 1:00	236512.86	0	69.3	0
4	1	1/1/2023 2:00	196980.48	0	57.71	0
5	1	1/1/2023 3:00	205876.09	0	60.32	0
6	1	1/1/2023 4:00	214273.11	0	62.78	0
7	1	1/1/2023 5:00	206910.03	0	60.62	0
8	1	1/1/2023 6:00	217125.98	0	63.62	0
9	1	1/1/2023 7:00	215581.34	0	63.16	0
10	1	1/1/2023 8:00	217104.58	-4990.69	63.61	-1.46
11	1	1/1/2023 9:00	225384.16	0	66.04	0
12	1	1/1/2023 10:00	222913.55	0	65.31	0
13	1	1/1/2023 11:00	217132.11	-4430.33	63.62	-1.3
14	1	1/1/2023 12:00	212440	0	62.24	0
15	1	1/1/2023 13:00	207178.09	0	60.7	0
16	1	1/1/2023 14:00	194966.64	-4515.55	57.12	-1.32
8753	365	12/31/2023 15:00	137000.81	-20082.88	40.14	-5.88
8754	365	12/31/2023 16:00	144640.08	-5458.13	42.38	-1.6
8755	365	12/31/2023 17:00	143858.42	-10708.88	42.15	-3.14
8756	365	12/31/2023 18:00	145330.83	-5447.36	42.58	-1.6
8757	365	12/31/2023 19:00	152864.66	-7417.53	44.79	-2.17
8758	365	12/31/2023 20:00	164165.61	-8520.86	48.1	-2.5
8759	365	12/31/2023 21:00	167607.88	-6248.61	49.11	-1.83
8760	365	12/31/2023 22:00	178886.27	-17821.71	52.41	-5.22
8761	365	12/31/2023 23:00	186027.41	-5196.52	54.51	-1.52
8762	365	12/31/2023	188571.27	-4975.73	55.25	-1.46

- Obtain 8760 hourly energy load set
- Heating and cooling load for every hour of a ‘typical’ year

How Confident Are You?

8760 building energy model



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How Confident Are You?

Soil thermal properties from testing

This report provides an overview of the test procedures and analysis process, along with plots of the loop temperature and input heat rate data. The collected data was analyzed using the "line source" method and the following average formation thermal conductivity was determined.

Formation Thermal Conductivity = 0.87 Btu/hr-ft-°F

Due to the necessity of a thermal diffusivity value in the design calculation process, an estimate of the average thermal diffusivity was made for the encountered formation.

Formation Thermal Diffusivity ≈ 0.58 ft^2/day

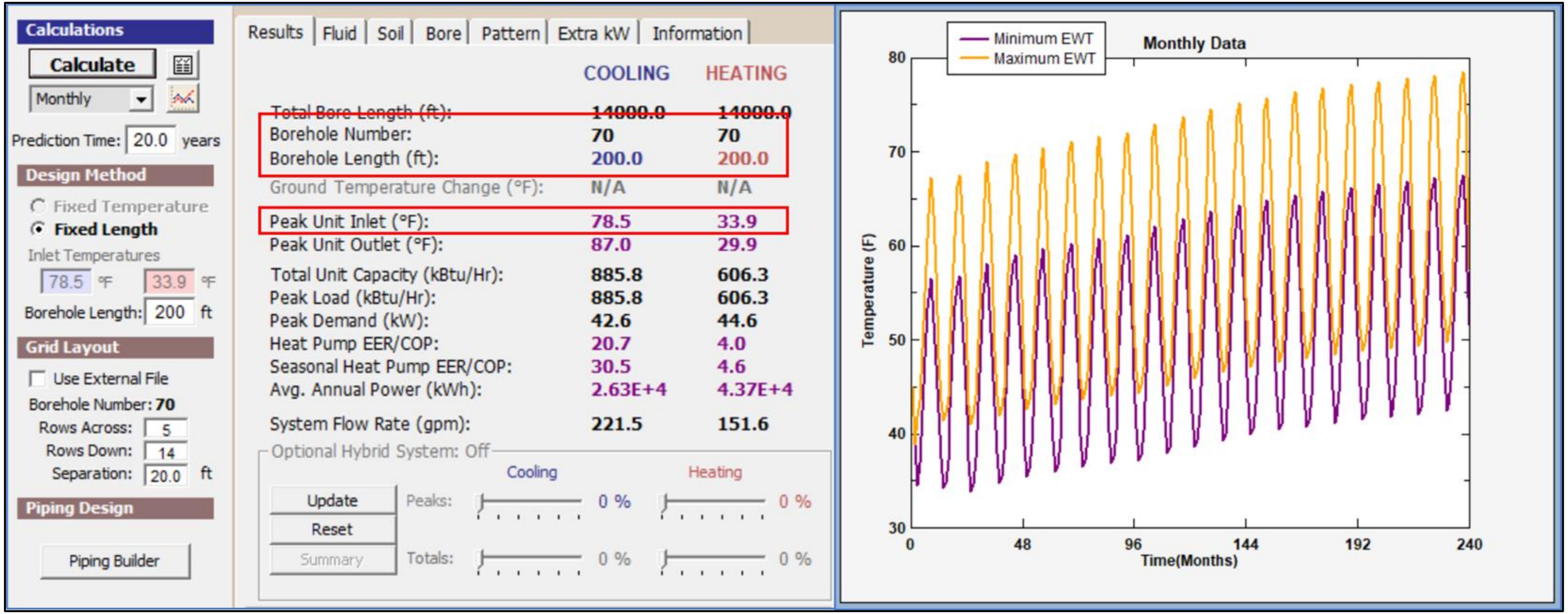
The undisturbed formation temperature was measured by lowering a temperature probe into the water filled U-bend prior to the start of the test.

Undisturbed Formation Temperature = 46.5-47.3°F, 46.8°F average

The formation thermal properties determined by this test do not directly translate into a loop length requirement (i.e. feet of bore per ton). These parameters, along with many others, are inputs to commercially available loop-field design software to determine the required loop length.

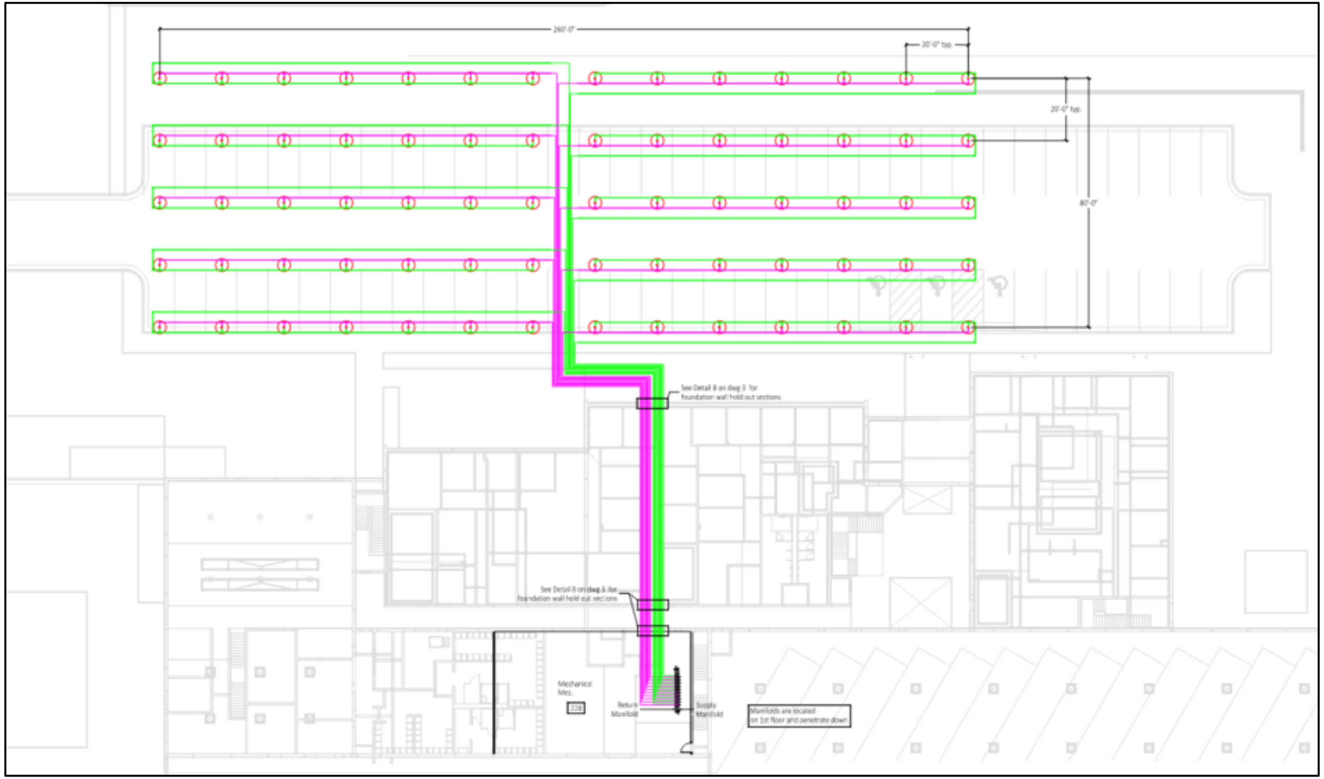
How Confident Are You?

GHX design calculations



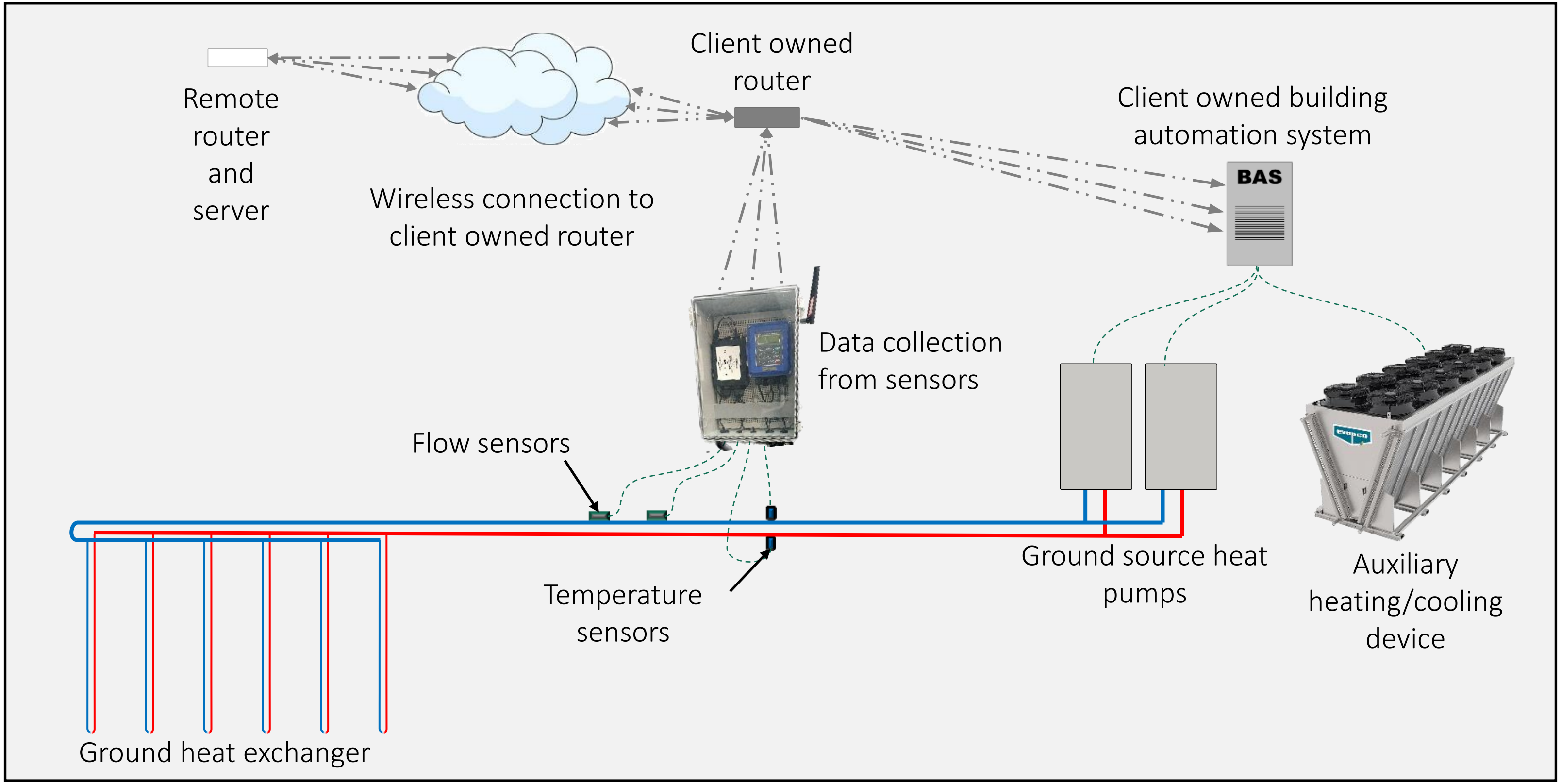
How Confident Are You?

GHX design construction drawings



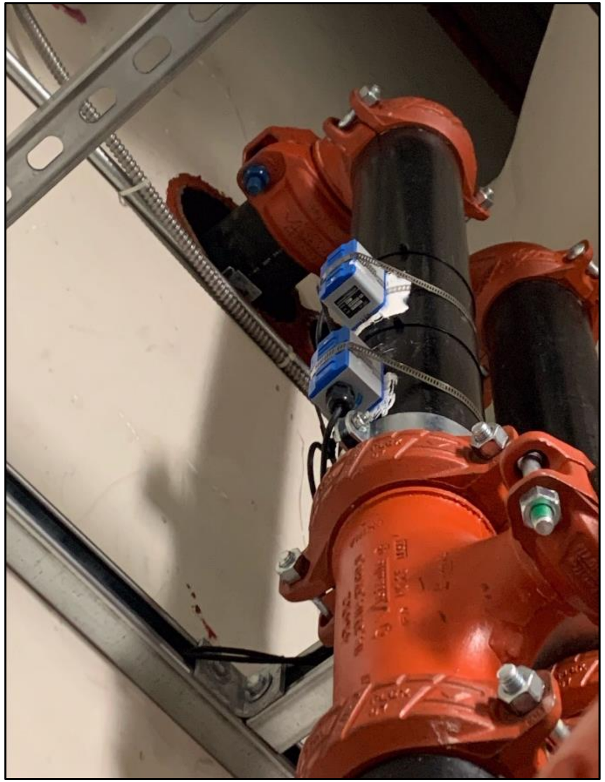
Ensure

Schematic of the data flow for Ensure system



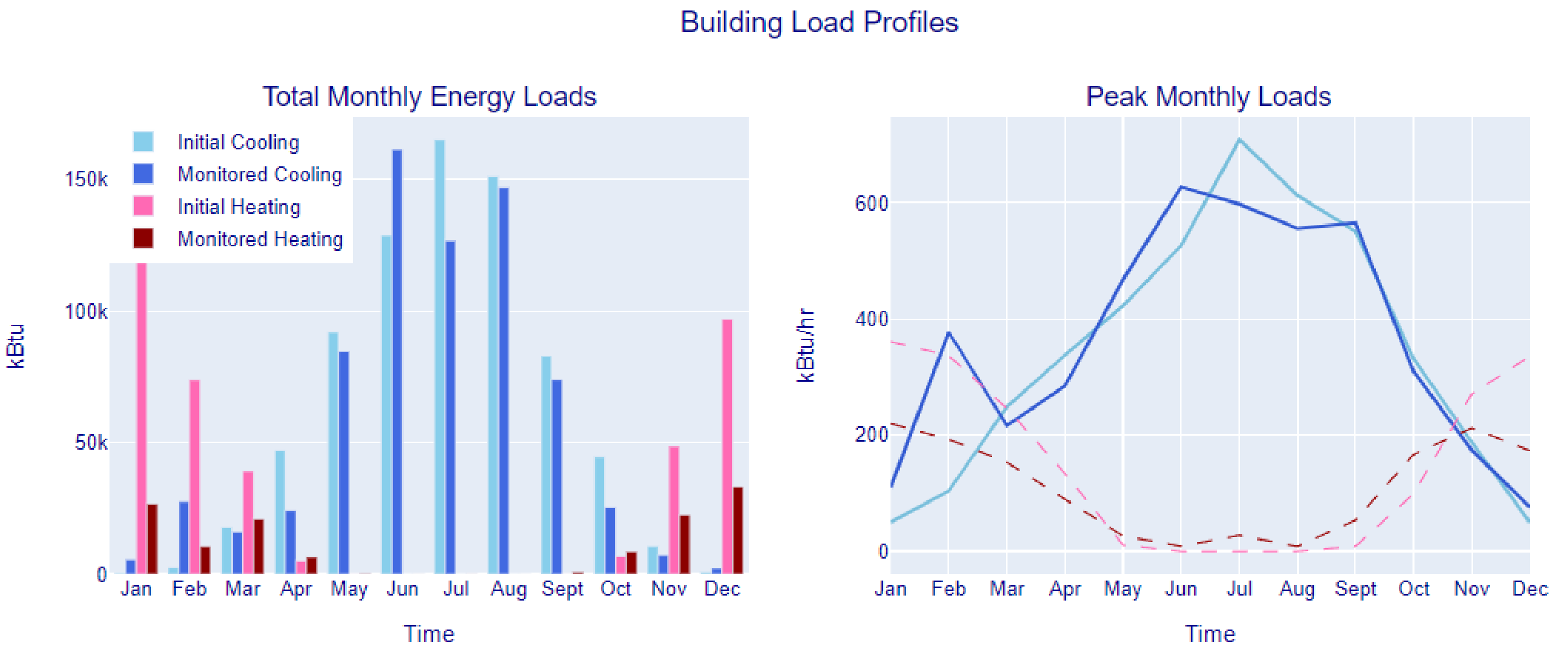
Ensure

Installation of Ensure in mechanical room



Ensure – Load Comparison

Comparing original energy model with real monitored loads

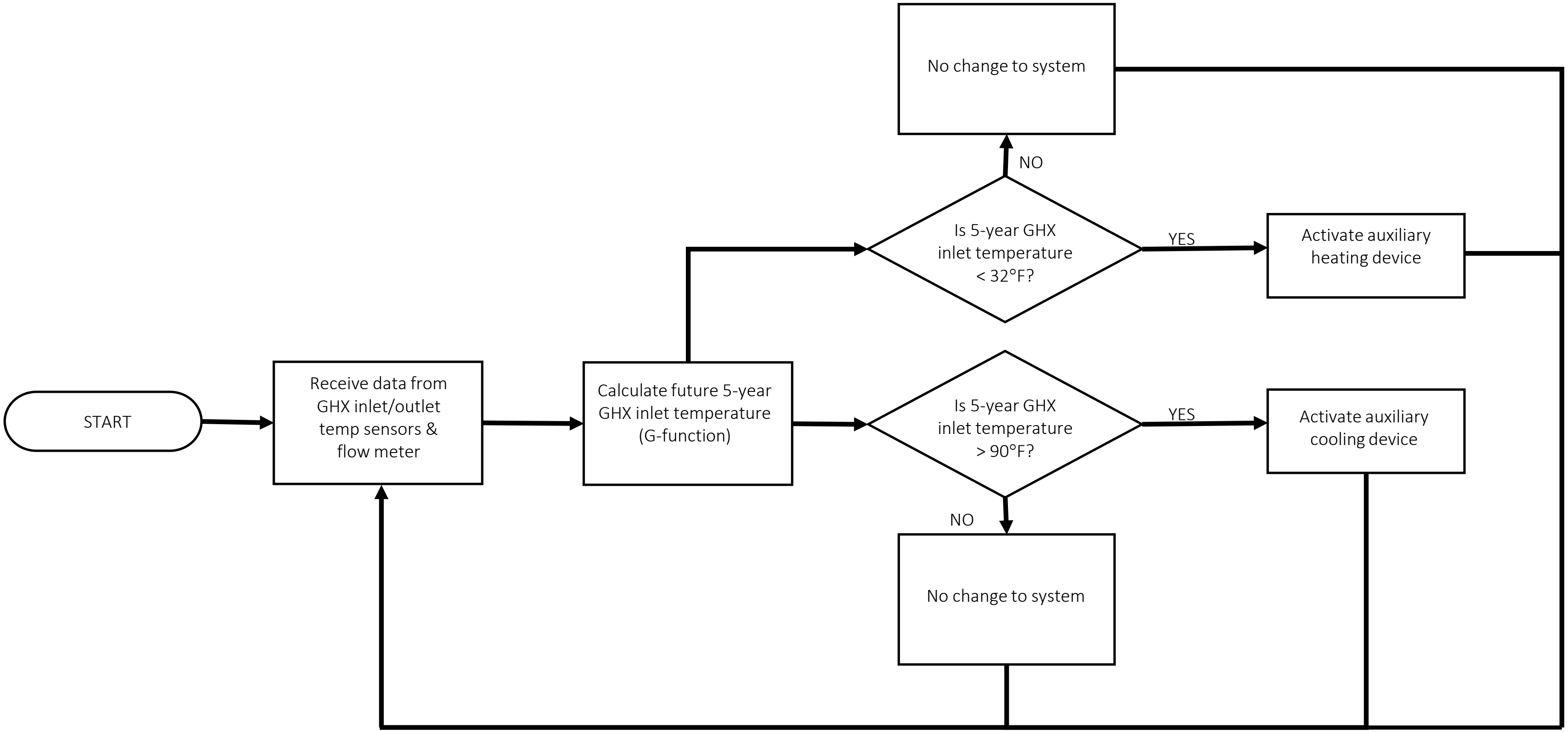


Ensure – Predictive Monitoring

Initial vs. monitored long-term GHX temperature trend

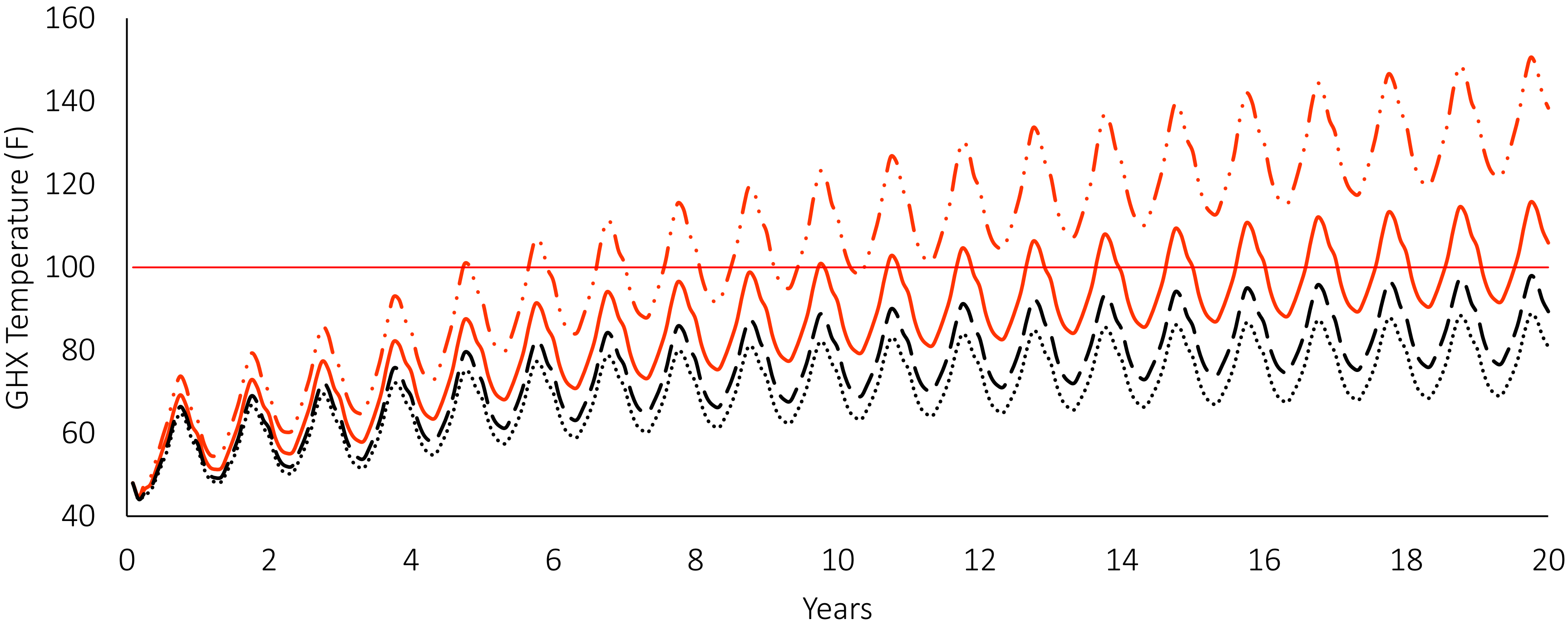
Ensure – Predictive Control

Example control sequence for signaling auxiliary heating/cooling device



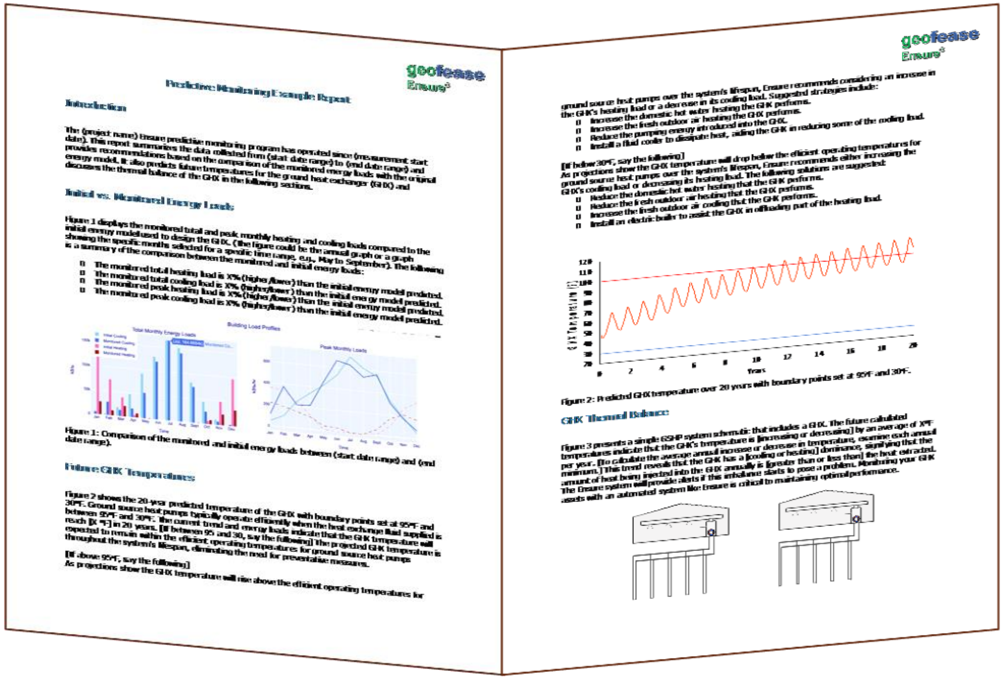
Ensure – Predictive Control

Example long-term GHX temperature control



Automated Reporting

- Automated reports for basic monitoring, predictive monitoring and predictive control advisor
- Includes summary of GHX performance during specified time interval
- Comparison of original energy model vs. real monitored loads
- Recommendations for optimized operation
- Future GHX performance predictions

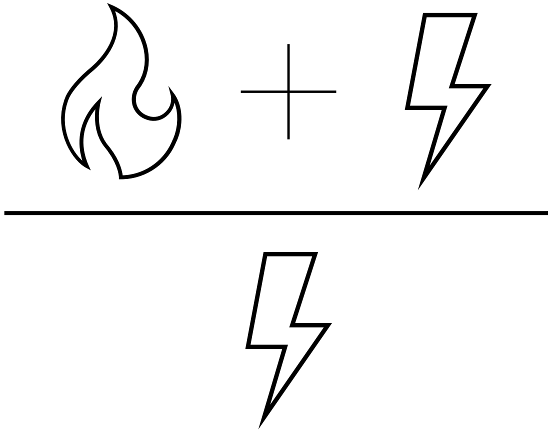


Q/A

Thermal & Electrical Metering

Coefficient of performance calculation

$$COP_h =$$



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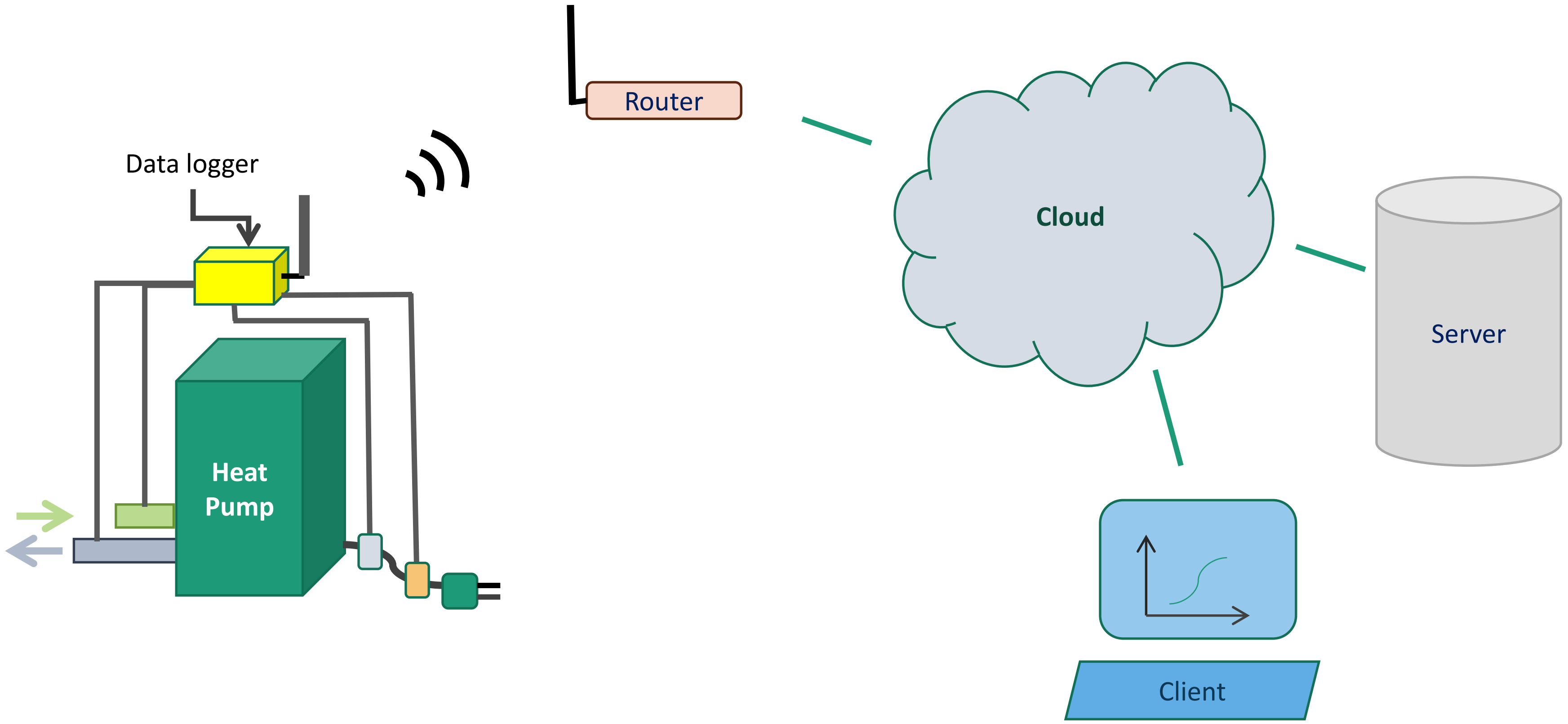
Vigilant

- COP meter & heat pump diagnostics tool
- Internet of Things device integrated with cloud-based analysis
- Communicates to remote server via internet connectivity
- Includes temperature sensors, ammeter, voltmeter, pressure sensors and flow meter

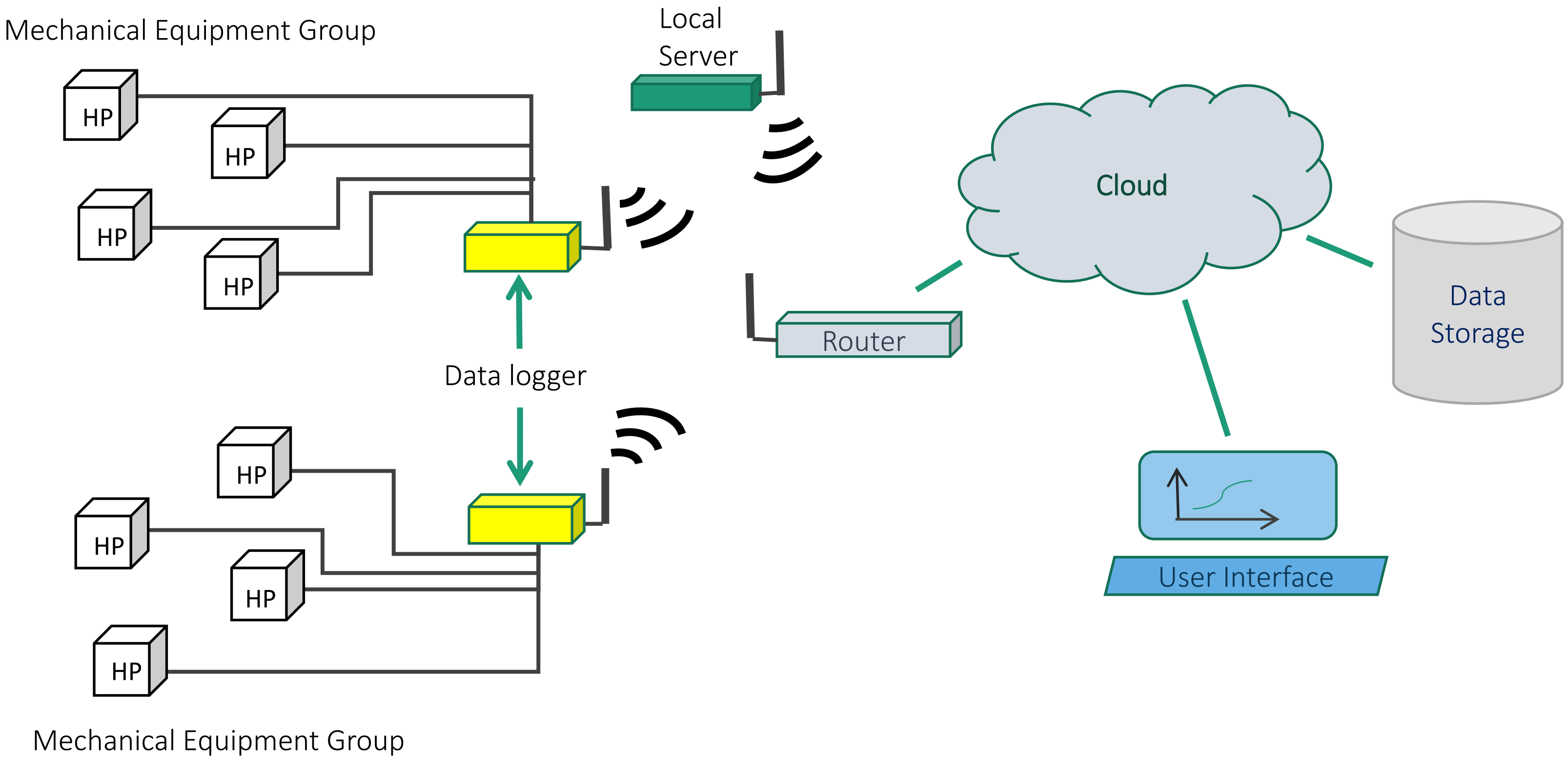
Vigilant – COP Meter

Schematic of data flow for individual Vigilant meter



Vigilant – Distributed Monitoring Solution

Schematic of data flow for distributed Vigilant system



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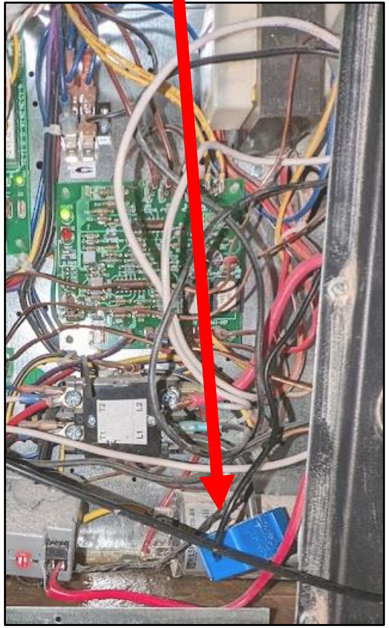
Vigilant

Installation of Vigilant in commercial mechanical room

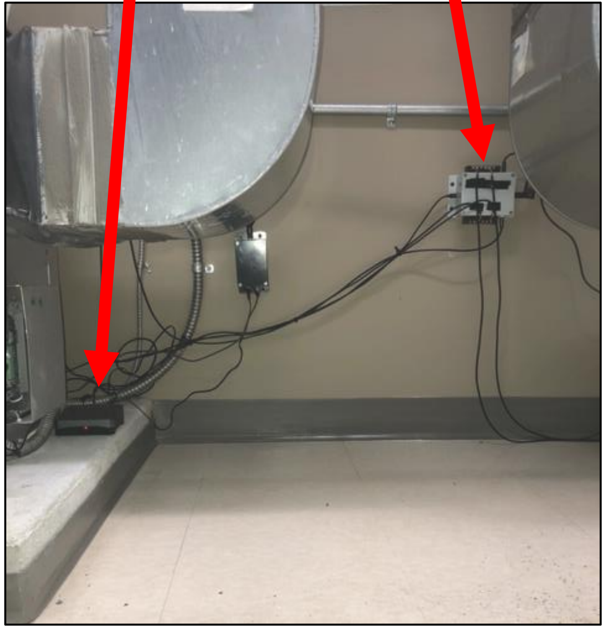
Ammeter



Vigilant meter

Local server

Vigilant meter



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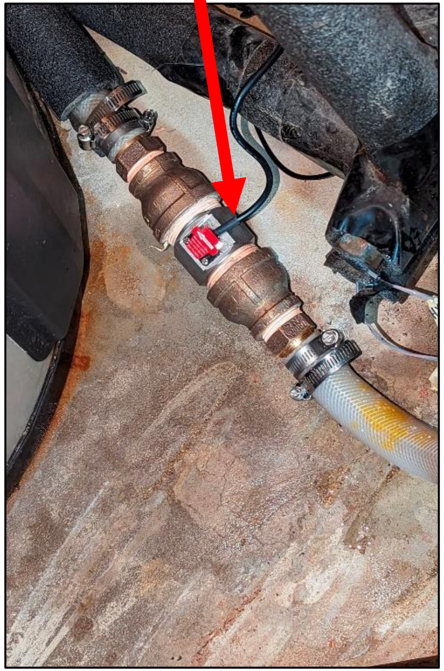
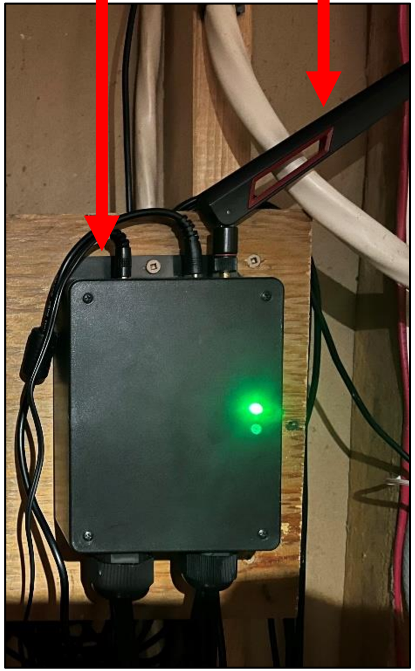
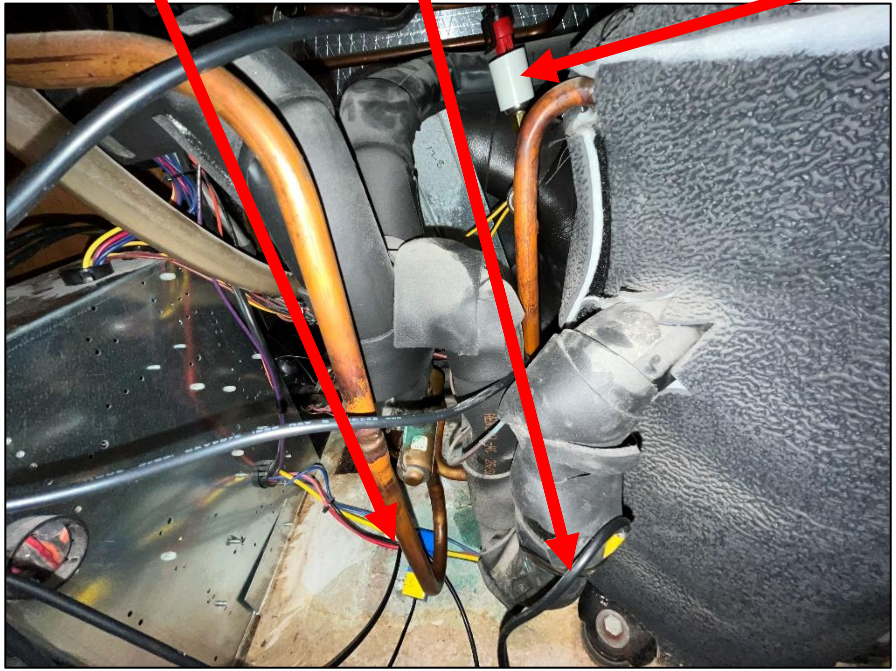
Vigilant

Installation of Vigilant in residential mechanical room

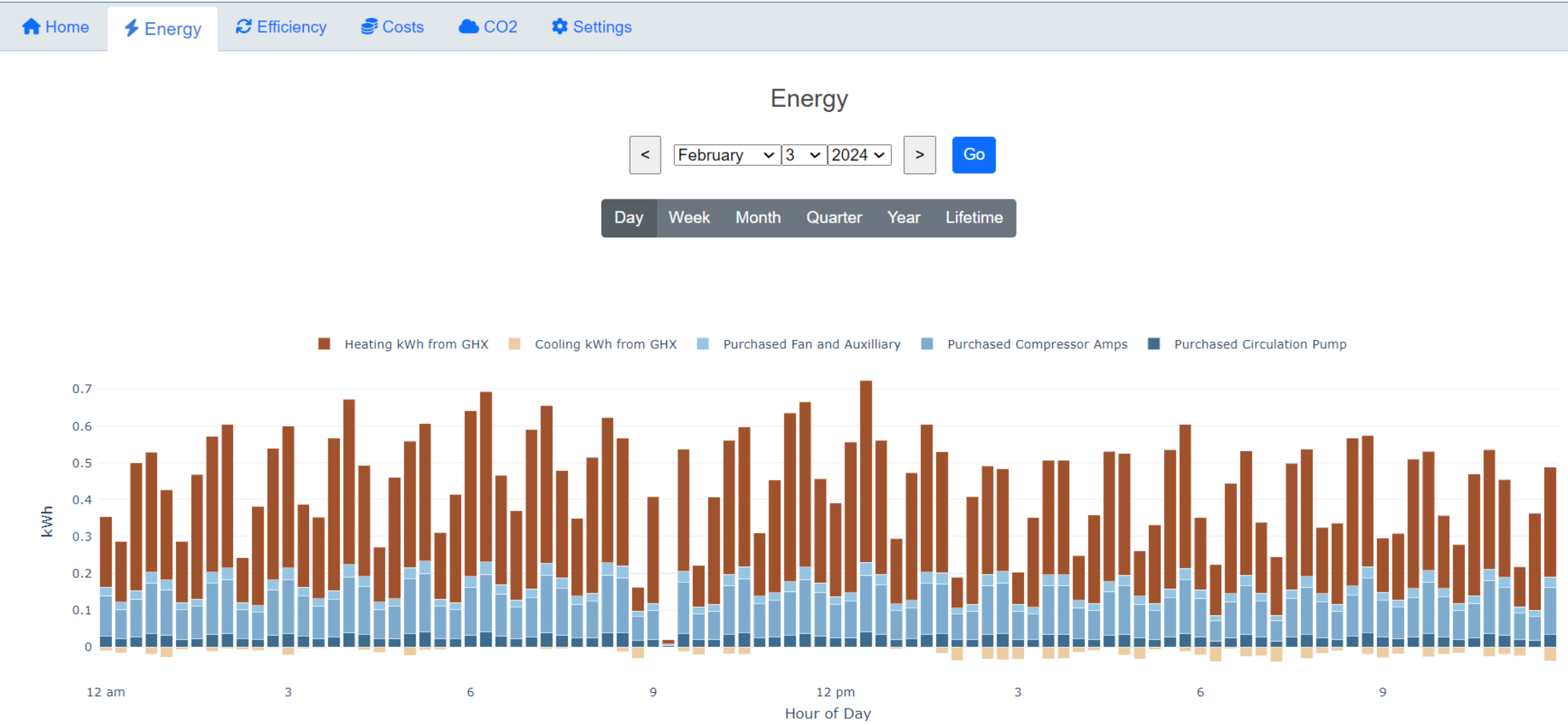






Vigilant – Data Visualization

Free earth and purchased electrical energy in kWh on daily scale

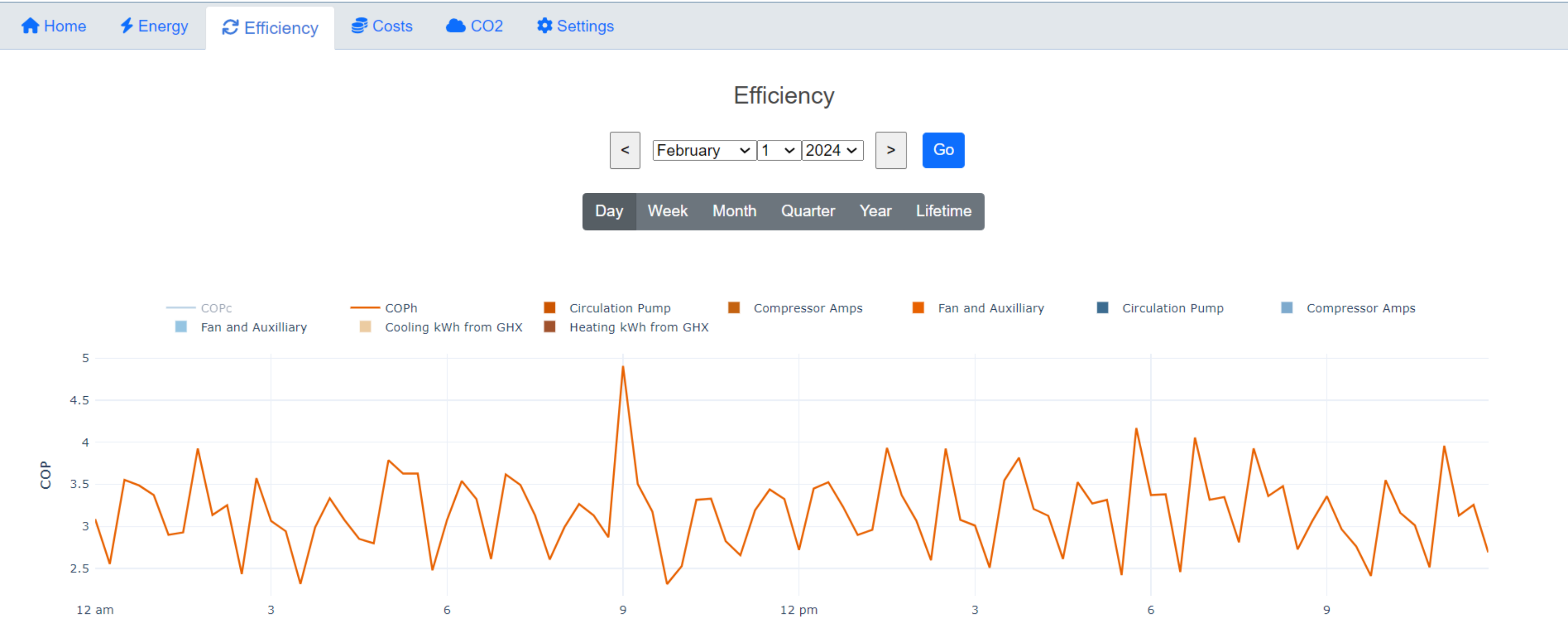


Vigilant – Data Visualization

Free earth and purchased electrical energy in kWh on annual scale

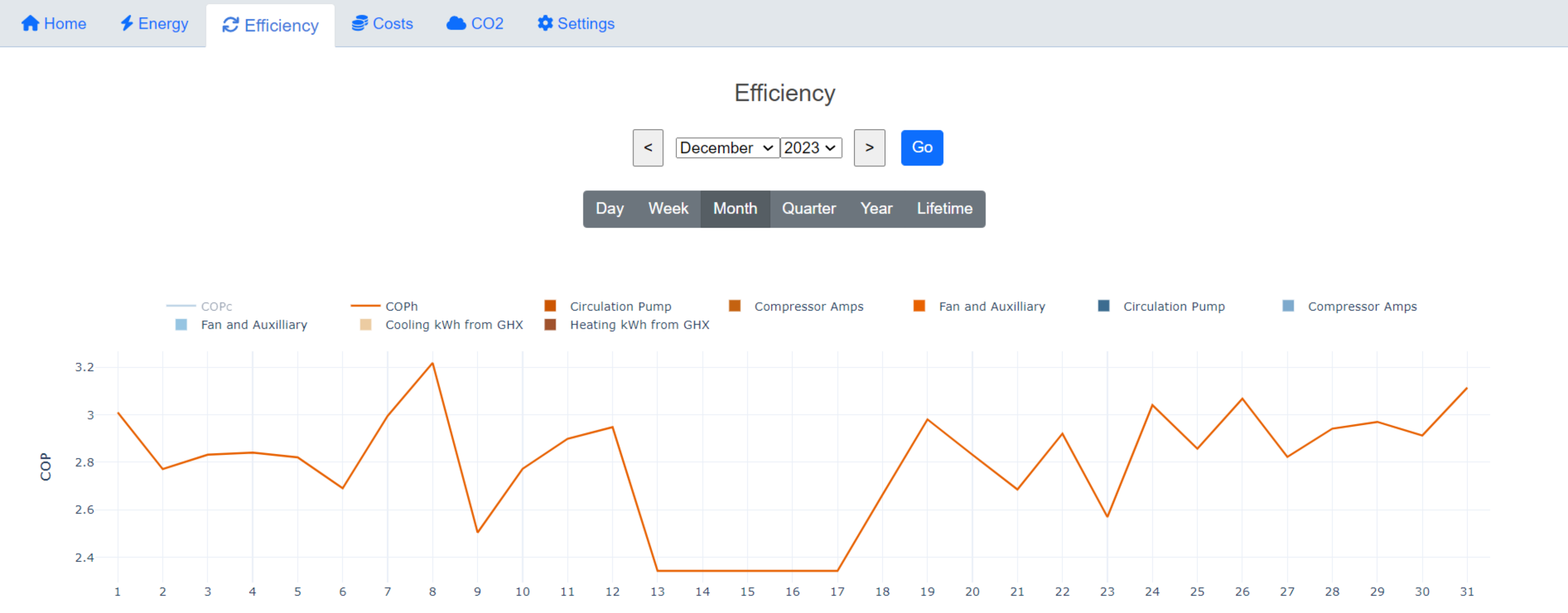
Vigilant – Data Visualization

Coefficient of performance on daily scale



Vigilant – Data Visualization

Coefficient of performance on annual scale



Vigilant – Data Visualization

User inputs

COSTS

Electric Utility

Electricity Cost [$ / kWh]

0.095

Electricity Base Cost [$]

9.33

Charging Frequency

per month

Alternate System

Alternate System Type

Gas

Alternate Fuel Cost [$]

0.5262

Energy Cost Unit

Cubic Meter [m^3]

Alternate Fuel Base Cost [$]

14.00

Charging Frequency

per month

ASHP COP - Cooling

3.00

CO_2 Information

CO2 Emissions - Electricity

0.12000

CO2 Emissions Units

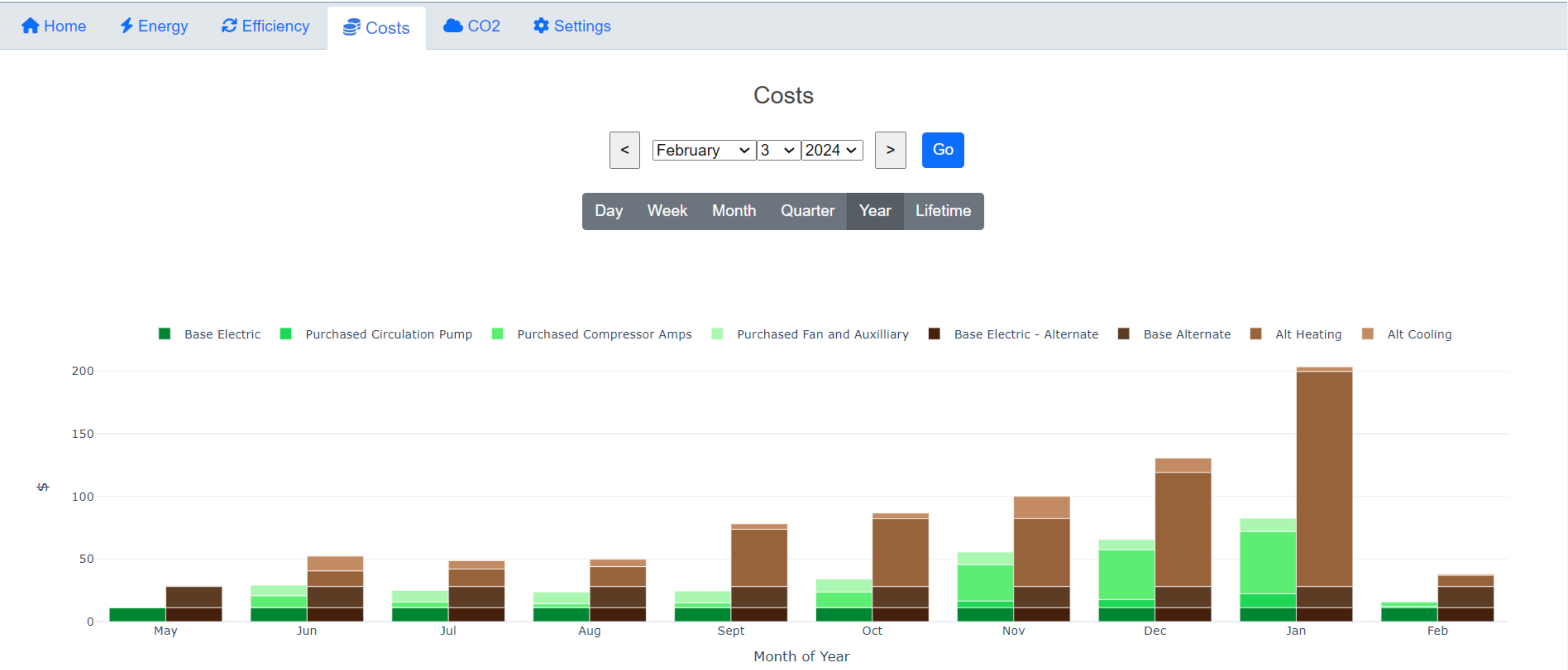
lbs / kWh

Vigilant – Data Visualization

Cost comparison on a daily scale

Vigilant – Data Visualization

Cost comparison on an annual scale



Vigilant – Data Visualization

CO_2 comparison on a daily scale

Vigilant – Data Visualization

CO_2 comparison on an annual scale

Geothermal Tools For Success

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