An Introduction to Geothermal Engineering and Energy Modelling

ENGINEERS GEOSCIENTISTS MANITOBA

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Interaction

- The course is being **recorded**
- **Cameras** and **Microphones** are **off**
- **Polls** to receive your ideas
- **Chat is open**
  - During Presentation and Q&A
  - Comments are welcome and will be monitored
  - Please send comments to **Everyone**
- Technical issues – send chat to **EngGeoMB**
- Follow-up handout with **survey**
  - Change **your name** in Zoom

Agenda

- Framework and importance
- Overview Energy Modelling
- Overview of Geothermal Engineering
- Q&A / Discussion

Presenters

- **Melanie Chatfield, P.Eng**

  Energy Modelling
- **Ed Lohrenz**

  Geothermal

Poll

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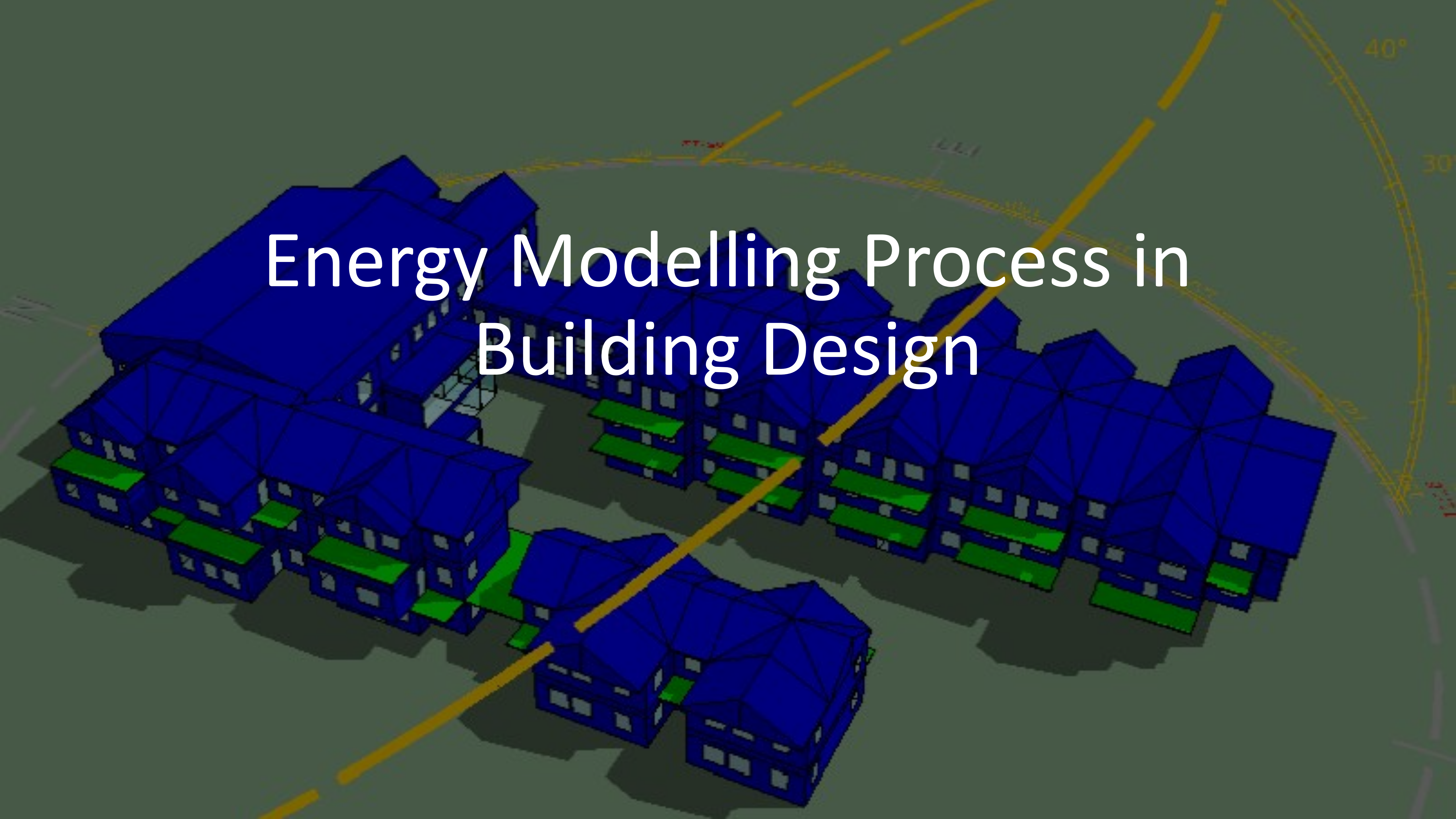
12:15

Energy Modelling Process in Building Design

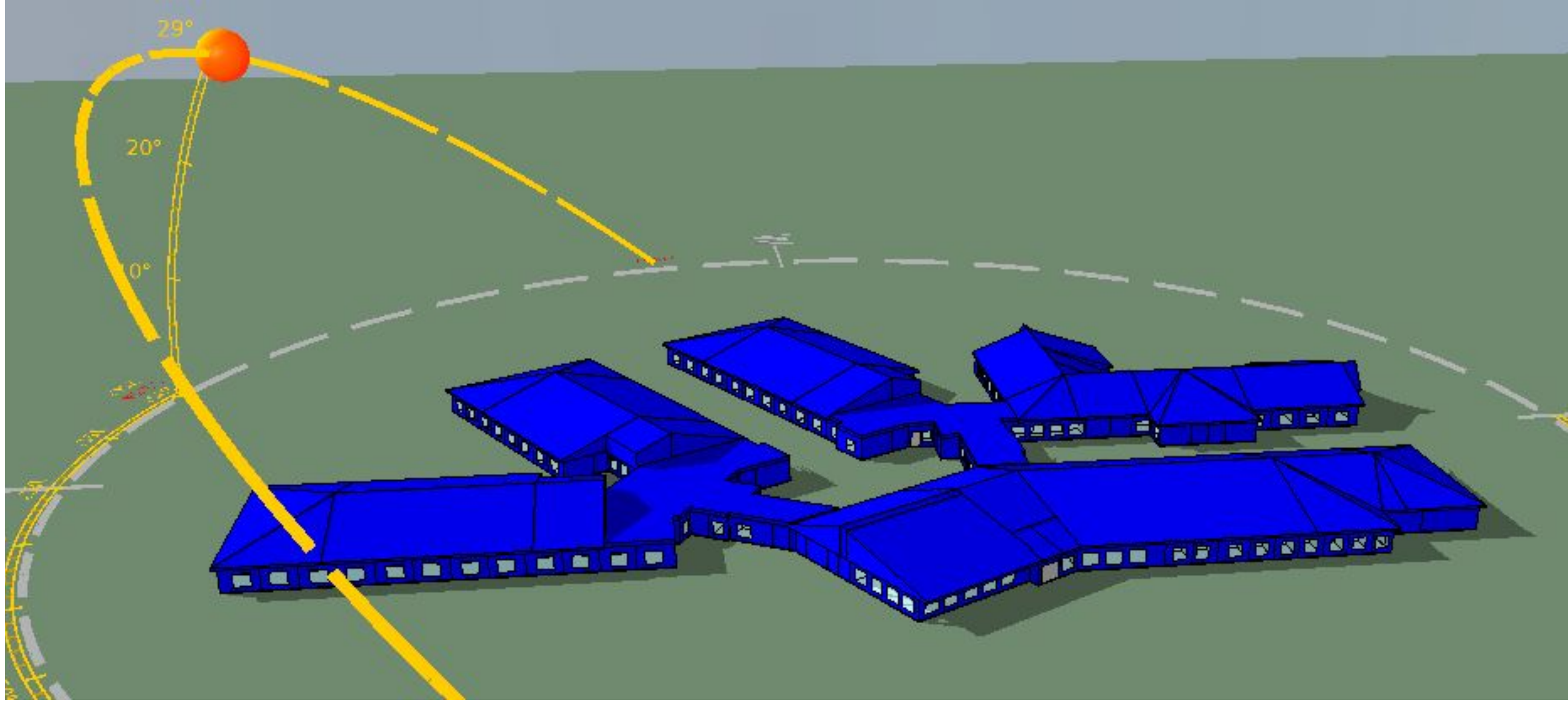


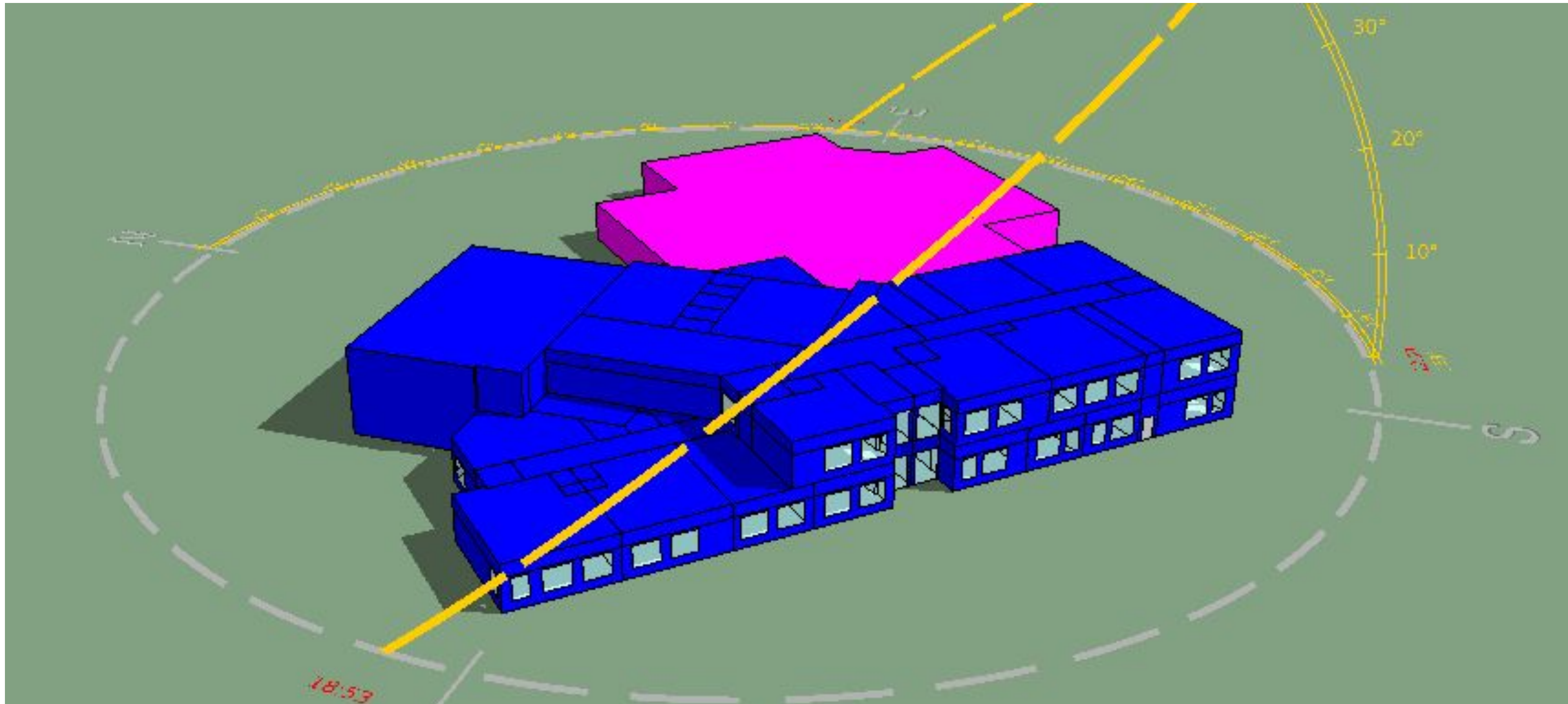
Agenda

1. What is Energy Modelling?
2. Heat and Mass Transfer in Buildings
3. What Tools are used
4. What is NOT considered
5. Applications
6. Modelling Process
7. Common Items That Create Uncertainty
8. Optimal Use
9. Load Model versus Energy Model
10. Output Reports
11. Geothermal Loads
12. Conclusion

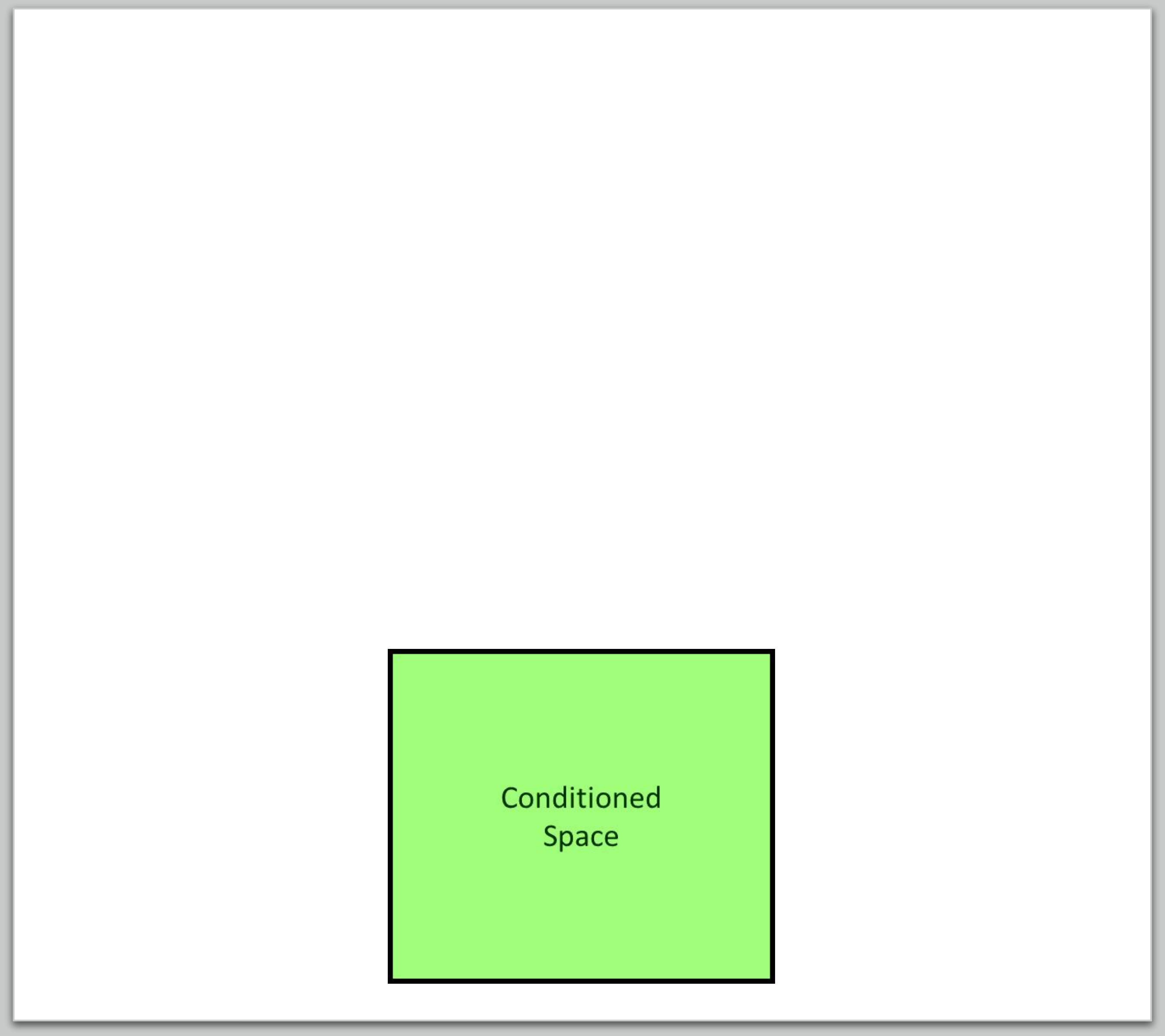
What is Energy Modelling?

The use of computer-based simulations to assess energy consumption, daylighting effects and other characteristics of a building design.

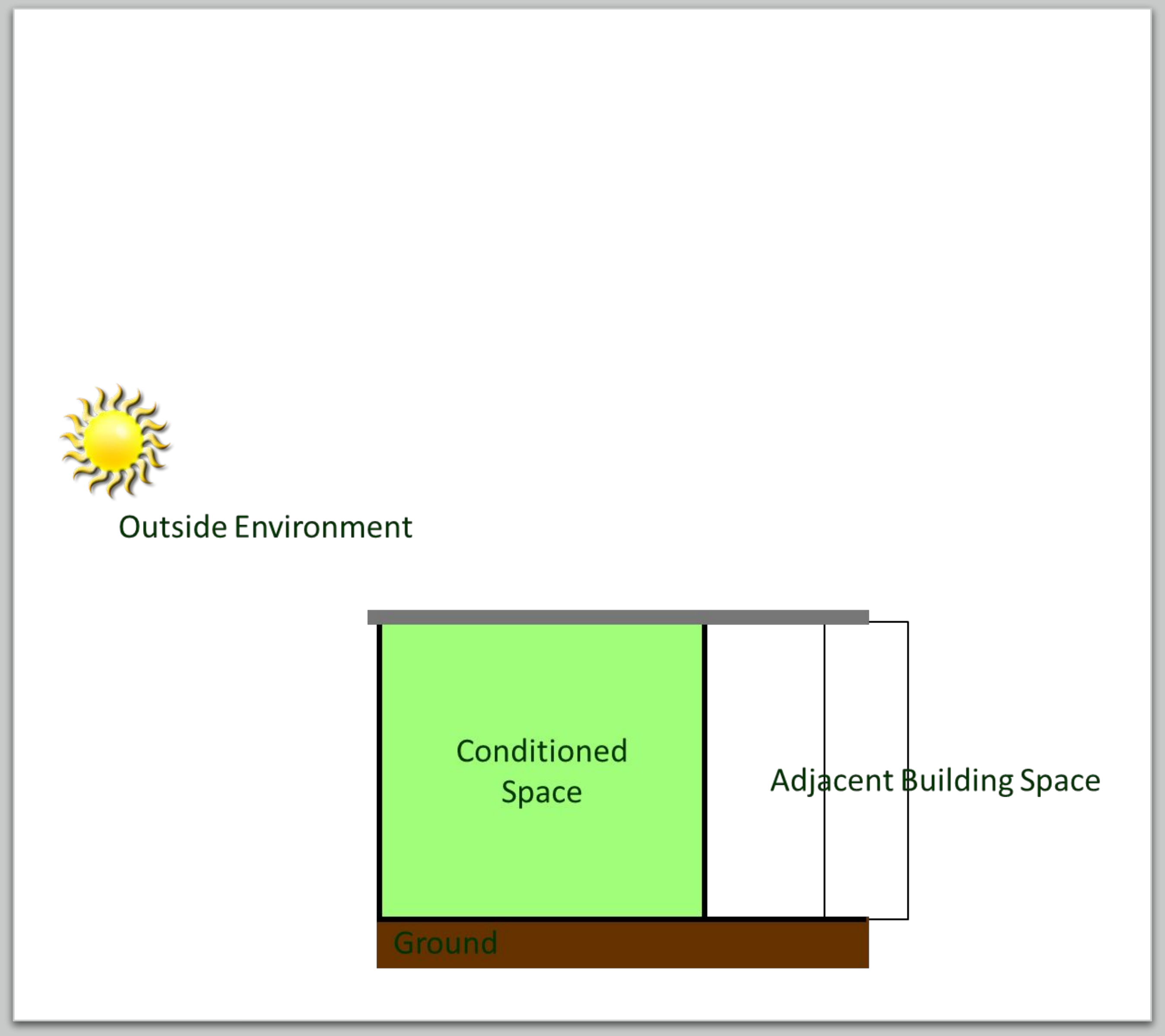




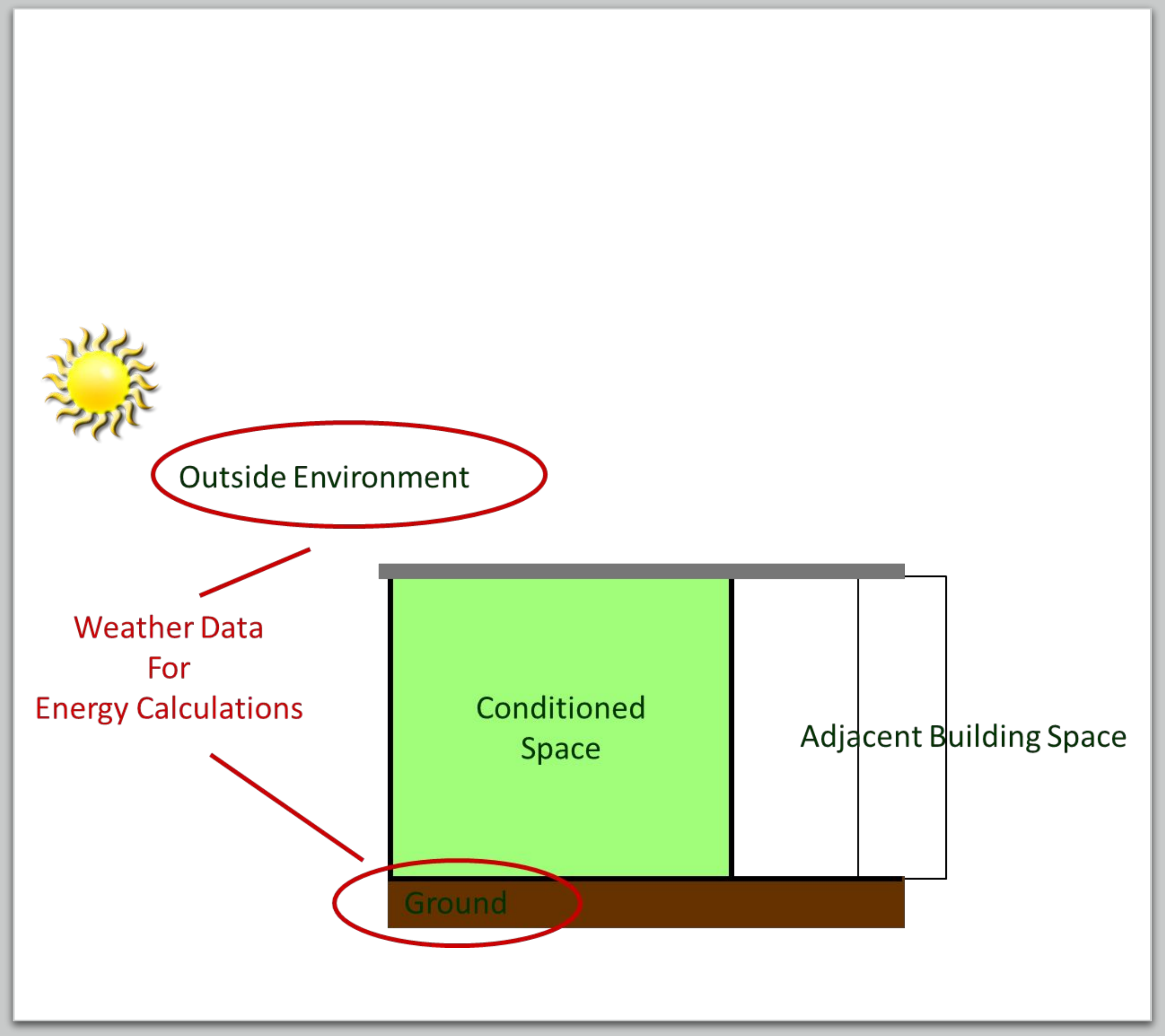
Heat and Mass Transfer in Buildings



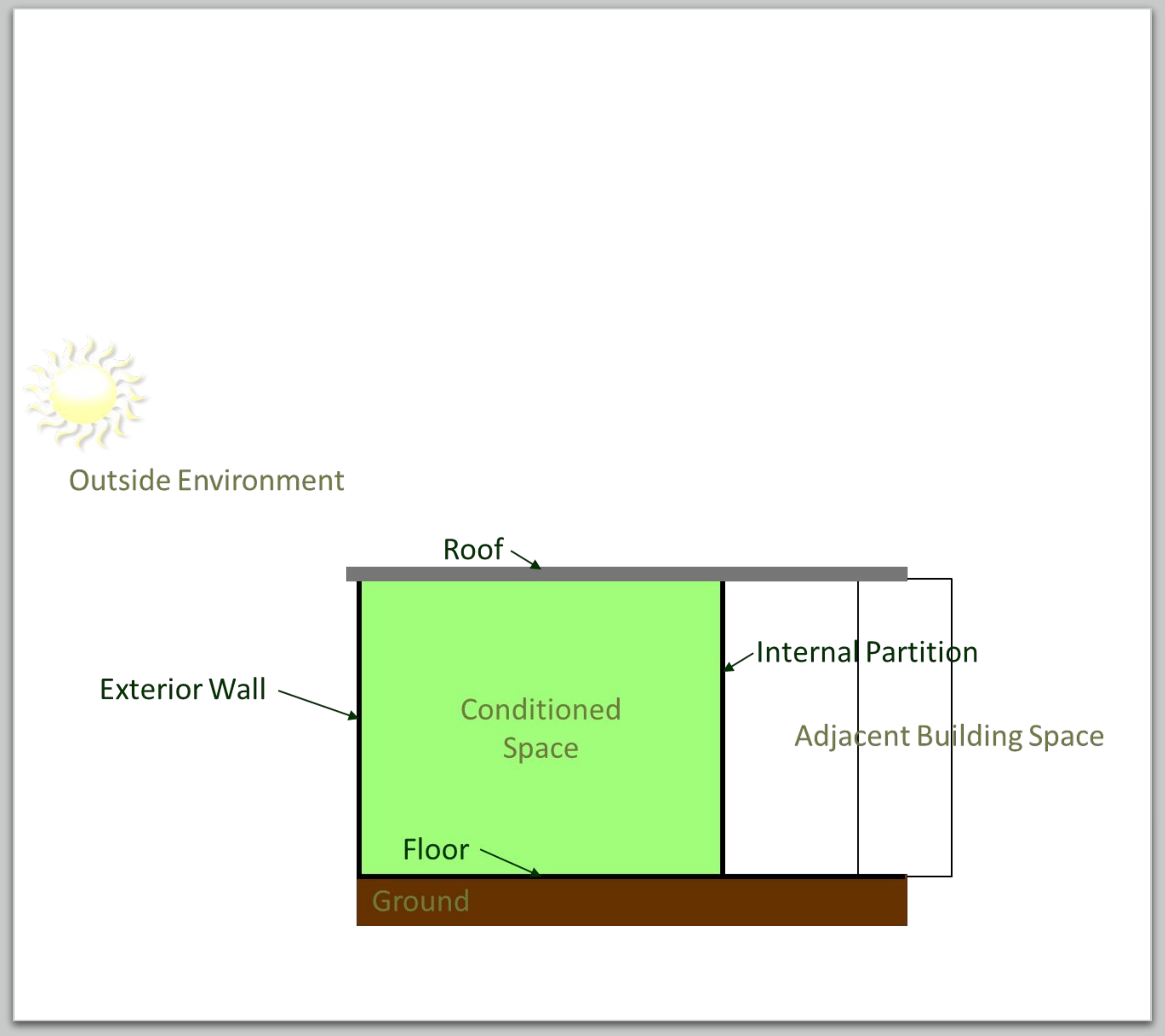
Heat and Mass Transfer in Buildings



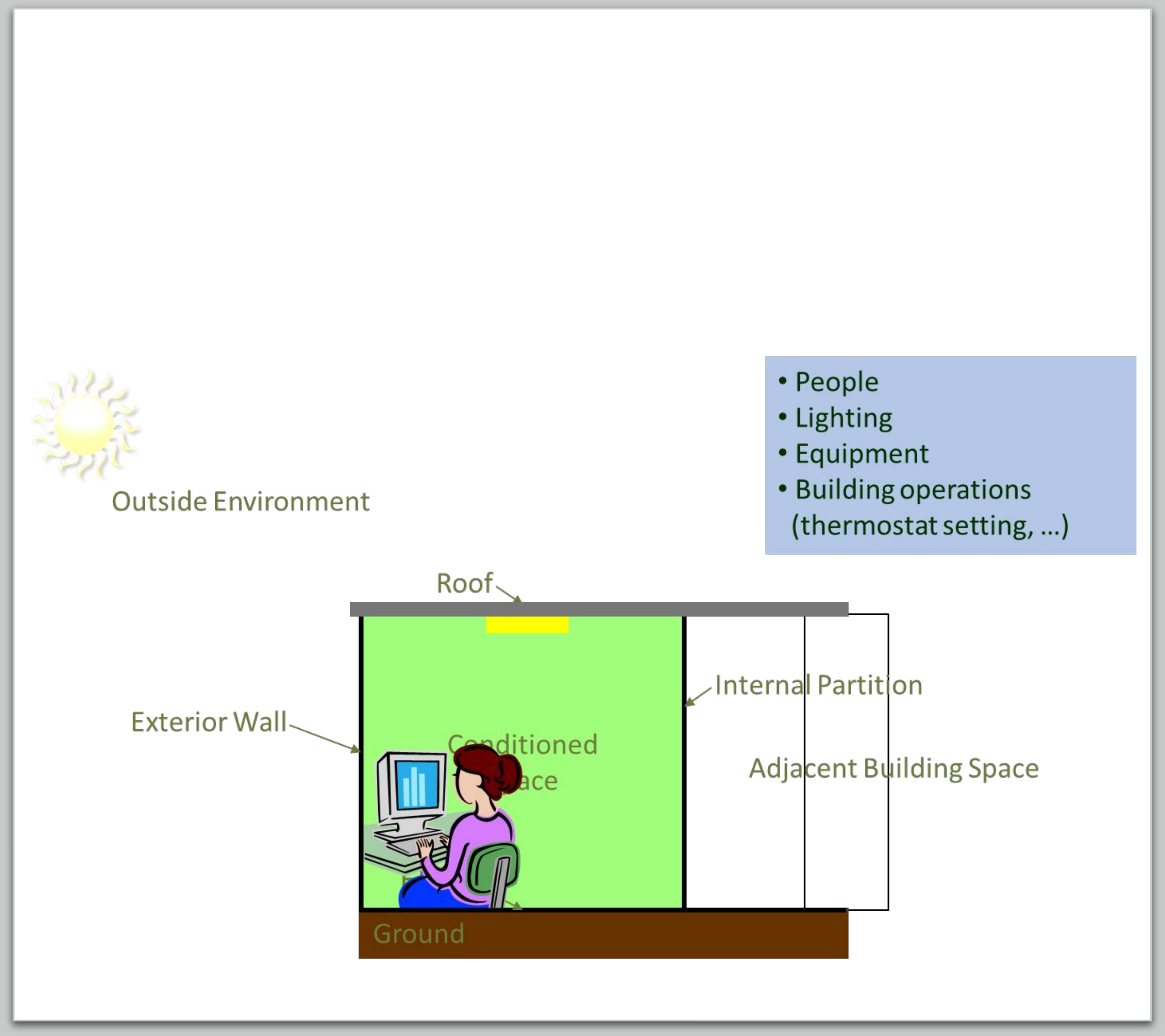
Heat and Mass Transfer in Buildings



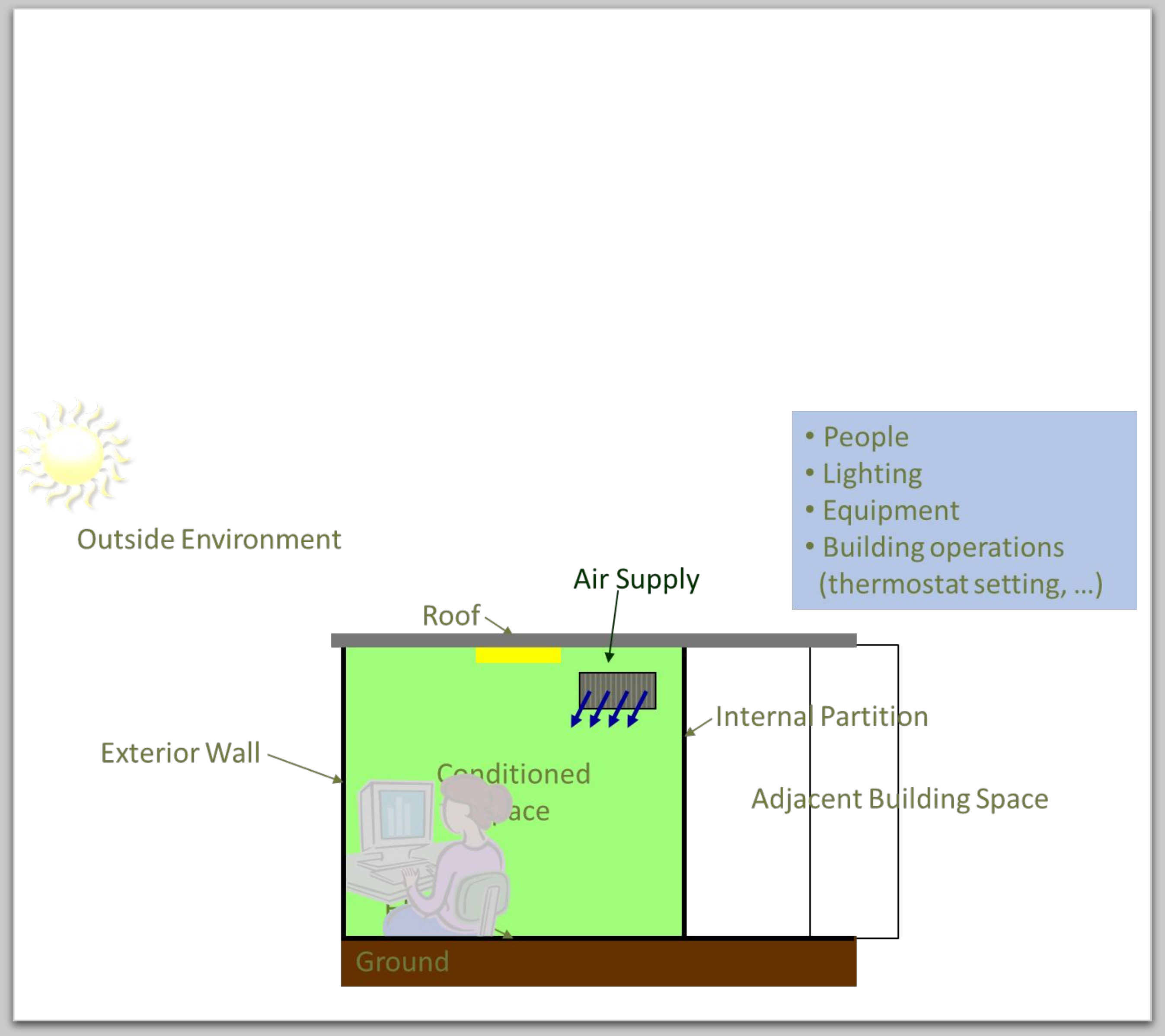
Heat and Mass Transfer in Buildings



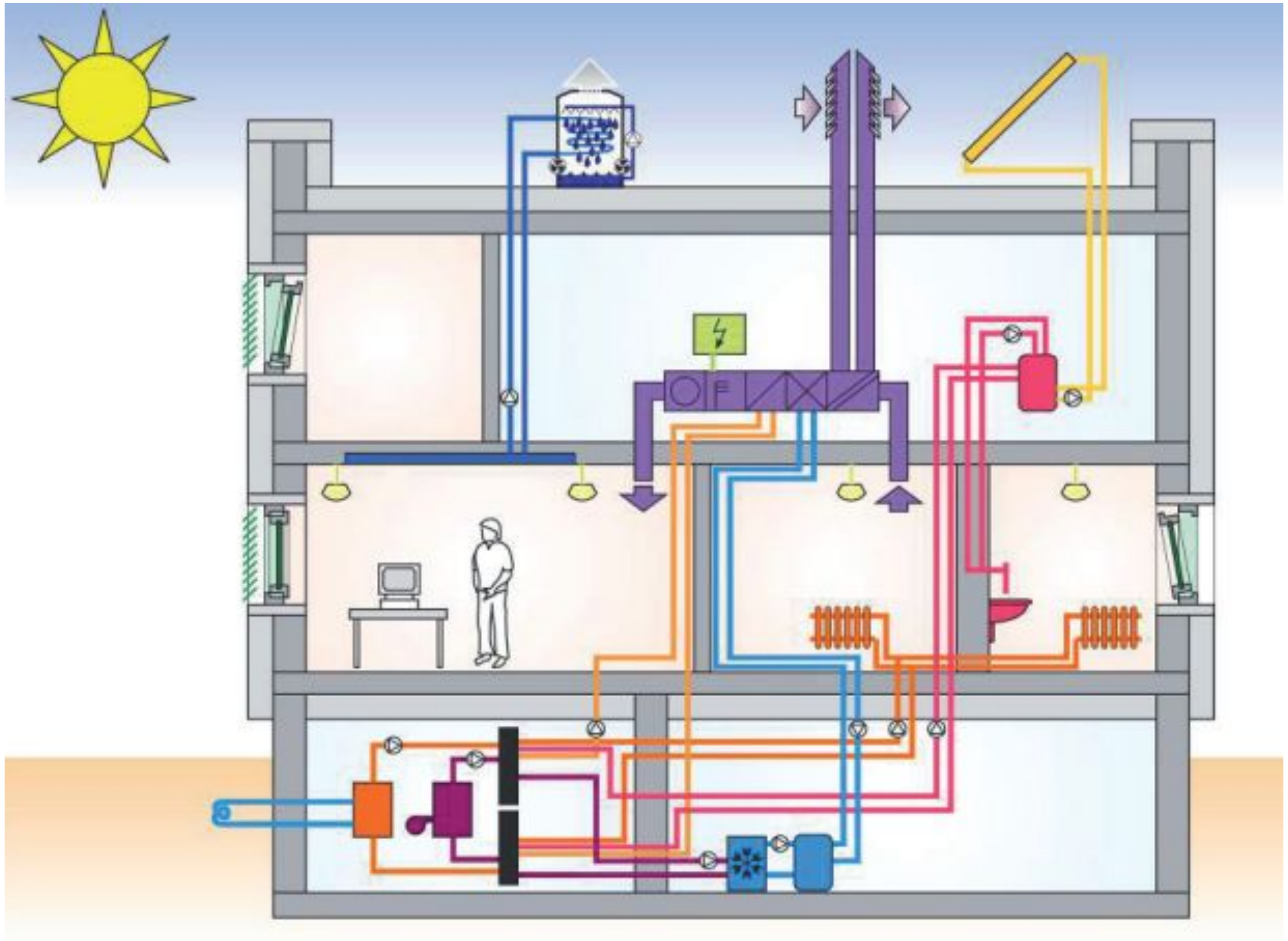
Heat and Mass Transfer in Buildings



Heat and Mass Transfer in Buildings



Building Energy Use



Source: https://www.iea-ebc.org/Data/publications/EBC_Annex_46_PSR.pdf

What Tools Are Used?

- RETScreen
- eQuest
- IES Virtual Environment
- Open Studio/Energy Plus
- Design Builder/Energy Plus
- Trane Trace
- Carrier HAP
- Sefaira
- Cove Tool

What Tools are Not Useful for Geothermal Sizing

- RETScreen – Has ground-source module but relies on user input for building heating and cooling loads
- Sefaira – Too high level
- Cove Tool – Too high level

*eQUEST: The bulk of the reporting focuses on energy (which is great for energy calculations of course).

What is NOT Considered

- The **fit out** by the occupants.
- The **equipment** added by the occupants.
- The **pattern of use** of the building & equipment.
- The **build quality** and **commissioning.**
- Actual **Infiltration** numbers.

Applications

- High Performance Building Design and Analysis
- Renewable Energy Feasibility Studies
- Net Zero Energy Studies
- Manitoba Energy Code for Buildings Compliance Modelling
- Analysis of Daylighting, and Solar Shading Design Strategies
- Feasibility studies for HVAC, Architectural and Electrical System Retrofits
- LEED & Green Globes Compliance Energy Modelling
- Digital Twins

Modelling Process Flow Chart

Software & Tool Selection

- Evaluate the appropriateness of the methodology by project phase, building type, climate etc.
- Select the optimal software and tools to meet output data needs, e.g., life-cycle cost analysis, individual component performance, energy use and demand etc.

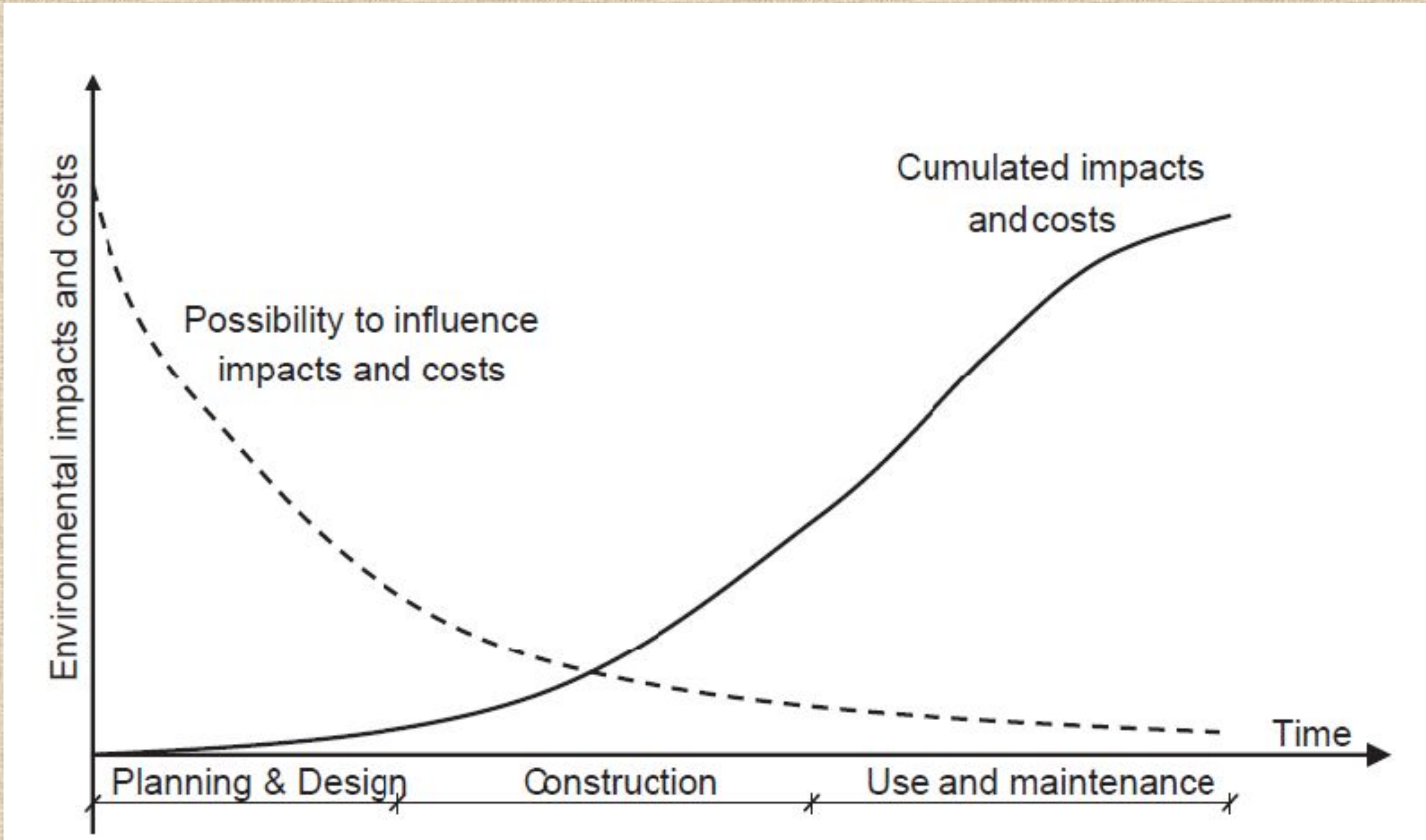
Inputting Components of Building & Energy Systems

- Location & Climate
- Building Envelope
- Building HVAC Systems
- Lighting Systems
- Other Internal & Process Loads
- Controls

Interpretations of Energy Model Results

- Verification and Troubleshooting of Simulation Results
- Analyzing and Comparing Modeling Results
- Economic Analyses
- Sensitivity Analyses

Modelling Process

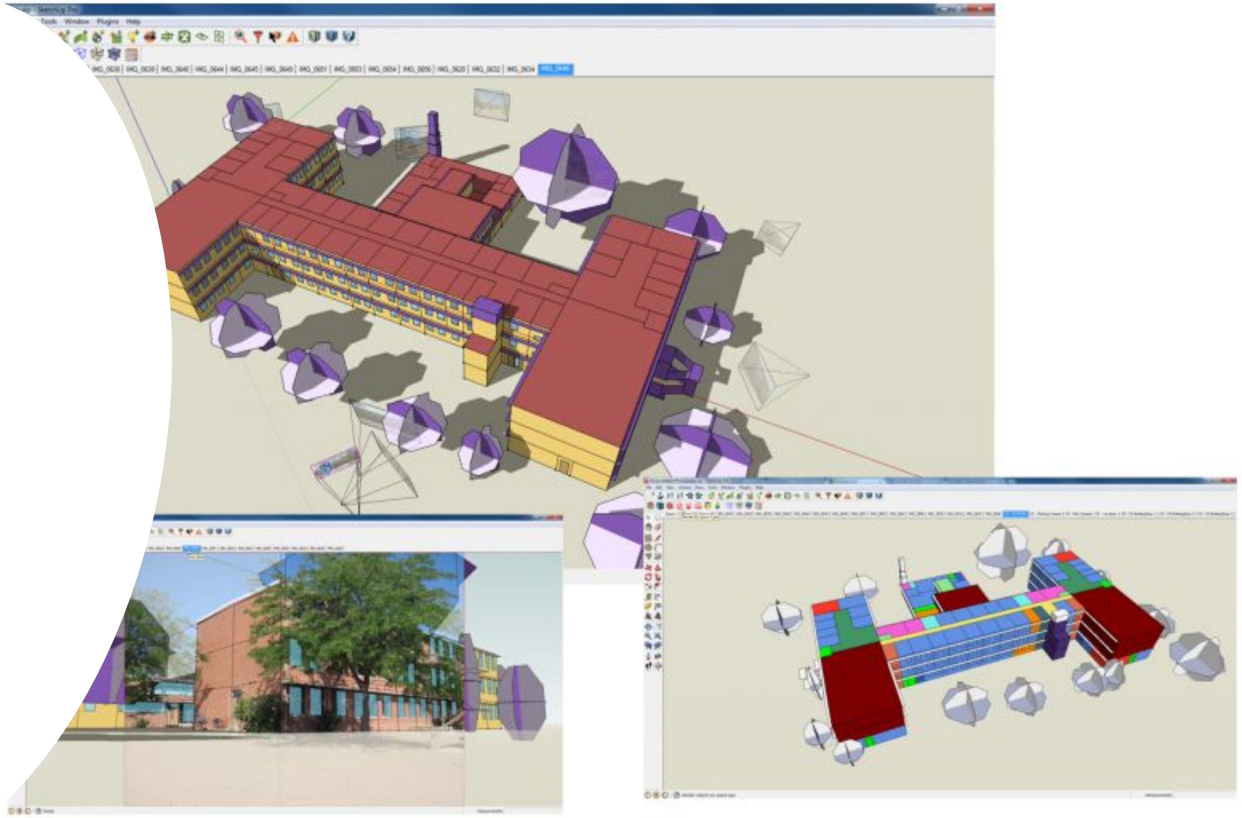


Reference: United Nations Environmental Programme (UNEP). Life-cycle analysis of the built environment. UNEP Indust Environ. 2003; 17 (21)

Common Items That Create Uncertainty

Examples Include:

- Thermal Bridging Calculations
- Material Properties
- Infiltration
- Complexity of Design
- Plug Loads
- Schedules
- Poor or No Commissioning
- Weather
- Energy Modeller Experience



Multiple parameters with a certain level of uncertainty can have a large effect on the final performance due to the aggregated effect of uncertainties.

Optimal Use

> **"All models are wrong, but some are useful"**
> George Best, Statistician

An energy model is a recording of all the bits and pieces in a buildings and that information can be used to predict energy flows in the buildings. Glorified accounting tool – nothing magical.

- Deploy a model for a specific reason to answer a specific question.
- Concentrate on peak loads along with energy use.
- The Engineering profession is very lax at looking at the actual building performance after construction has been completed. We must start to learn from previous projects by performing measurement and verification.

Optimal Use

- **Modelling is not manipulation of software.** It's applying strong understanding of heat transfer physics, HVAC systems, weather and people. Knowing the software is not enough. First you need to know what is supposed to be happening in and around the building. Second, you need to know how to tell the software to do the same thing. When the software can't model your building or system exactly (and that happens a lot), the modeller needs to know how to create a reasonable alternative. **As a client, review an energy modellers experience.**

- **A thorough process of reviewing input is crucial** a there can be literally thousands of inputs. Reviews should be conducted by another experienced energy modeller within the same company or a third-party reviewer if that is not possible. **As a client, ask about the review process.**

- **Output review is the only way to have any confidence that the software is doing what is expected**. It is much preferable to be able to review hourly values for every system and central plant. Many models with reasonable looking output can become much improved after reviewing the details and discovering a key error. **As a client, ask about the review process**.

- **Every modeller needs to understand that no model will be perfect.** A modeller may have spent a few hundred hours on a model but should understand the end product they are aiming for. **As a client, understand that no model will be perfect, but that it should be useful to your project.**

The Difference Between a Load Model & an Energy Model

- **A load model will calculate the equipment sizes.**
  - A load model will typically add safety factors affecting fan sizes, coil selections, duct and piping, control valves, chillers and boiler sizes
  - Output reports are usually tailored for load calculation and work well for that purpose.

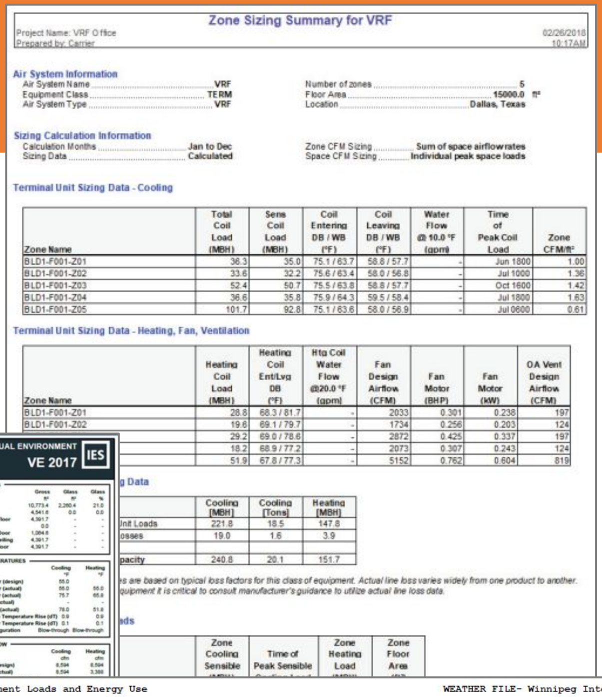
- **An energy model uses the actual equipment performance including how much it has been oversized by.**
  - Recording of all the bits and pieces in the buildings and we use that information to predict energy flows in the buildings. Glorified accounting tool – nothing magical.

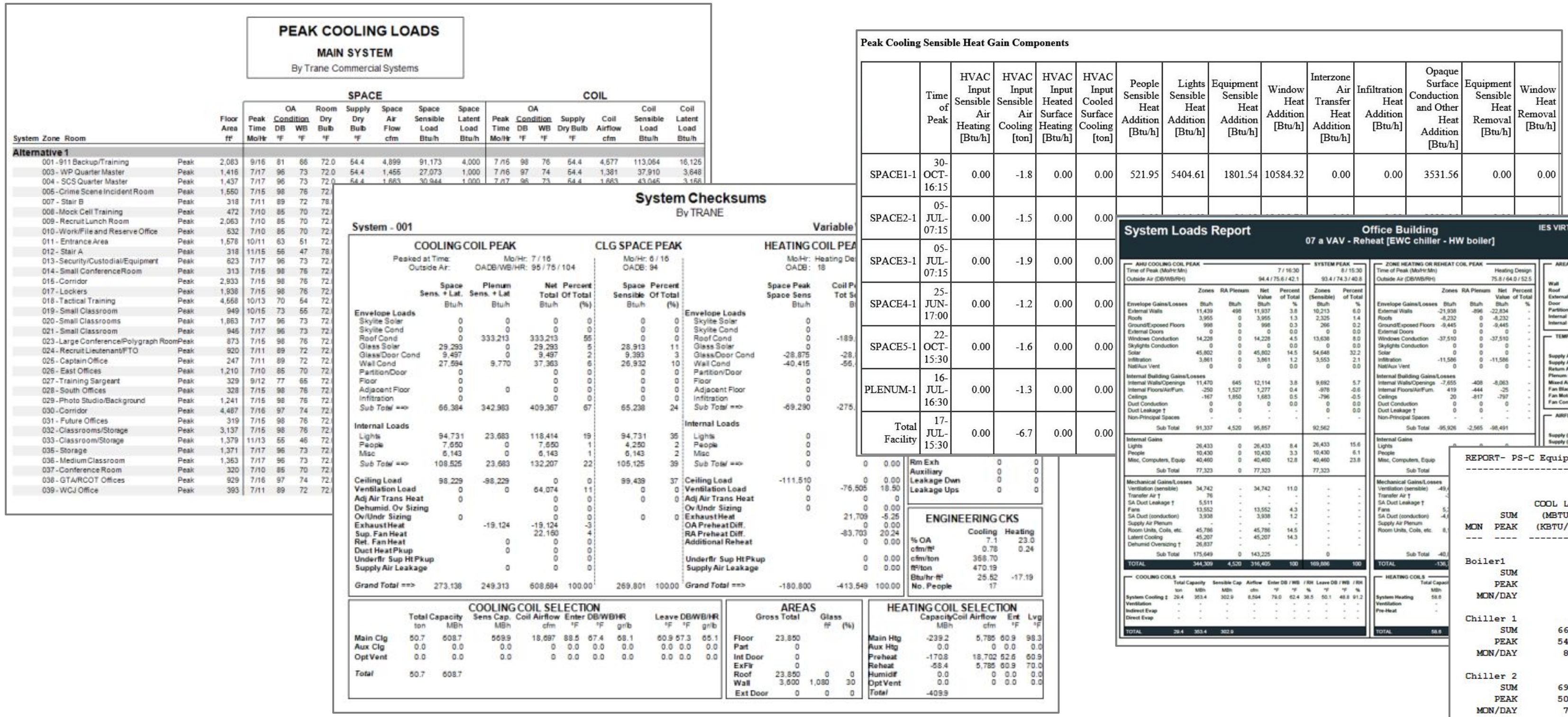
Carrier

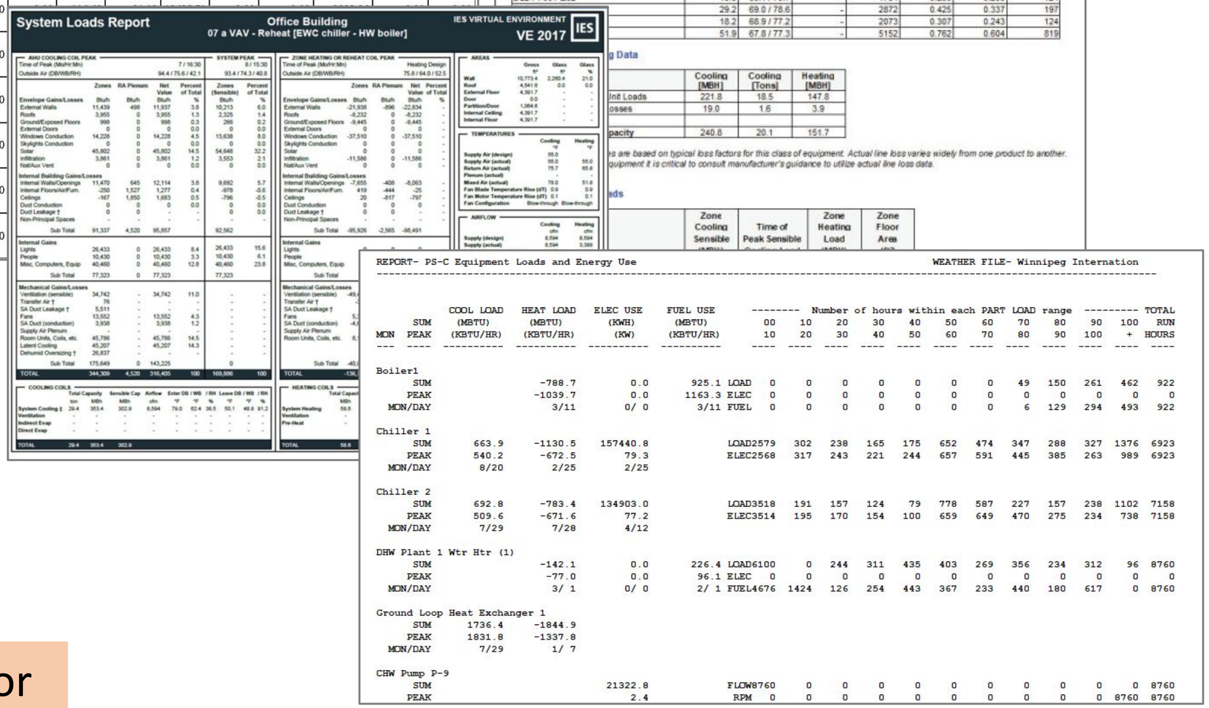
HAP

HOURLY ANALYSIS PROGRAM

Output Reports



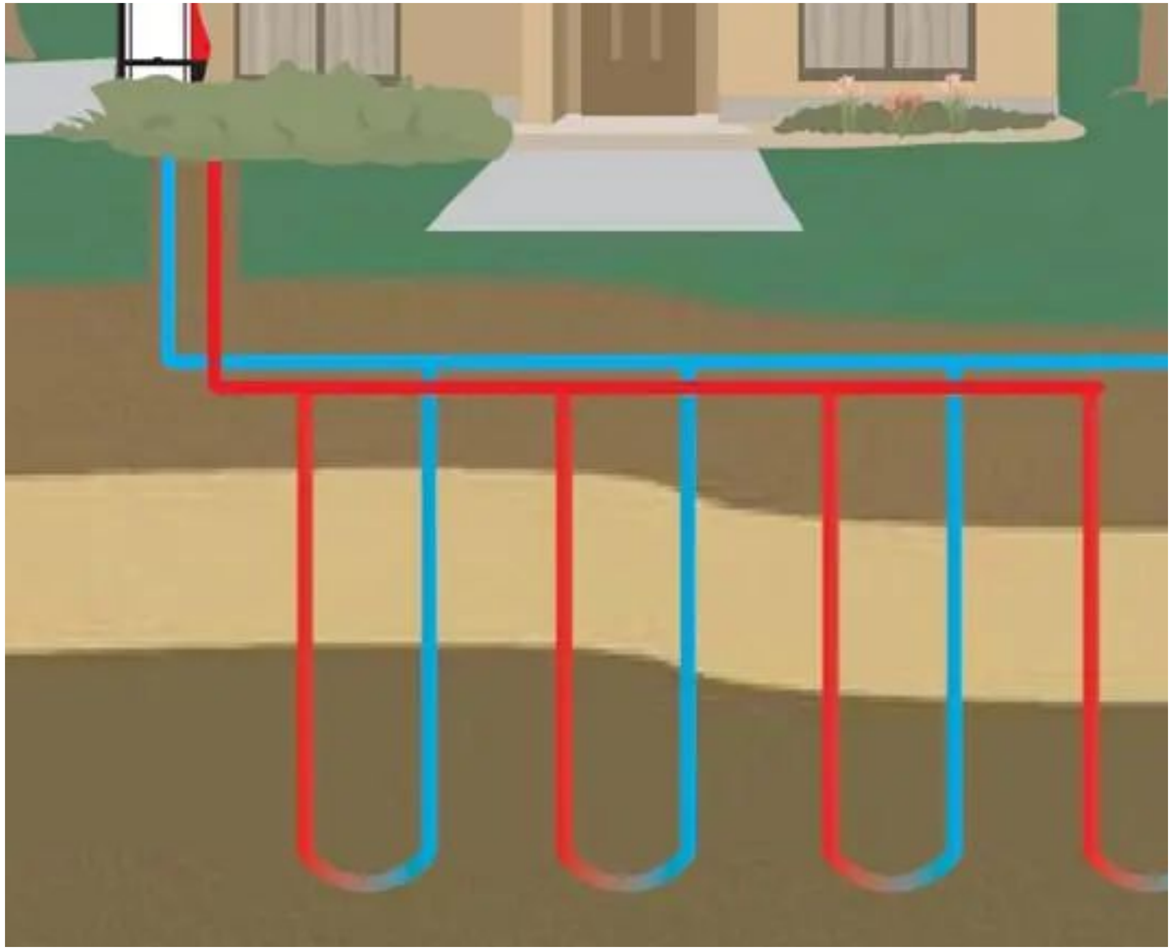




https://energy-models.com/tools/equest-load-extractor

Ground Source Heat Pump Loads

- Demand and load need to be both considered.
- Any simultaneous heating and cooling loads must be included as they form part of the loads.
- The loads need to be for equipment attached to the ground loop only – i.e. not electric vestibule heating
- You will need to extract the hourly building cool load (coils+losses&gains) and building heat load (coils+losses&gains) for a full year.



Ground Source Heat Pump Loads

Energy modelling software is designed to provide a buildings overall loads and peak loads. It is not designed to size well-fields for Ground Source Heat Pumps but there are several programs that can perform these calculations. Two of these include:

Ground Loop Design (GLD) enables you to design and compare vertical, horizontal and pond systems. http://www.GEOCLIP.com.

GLHEPRO is developed as an aid in the design of vertical borehole-type ground loop heat exchanger. https://hvac.okstate.edu/glhepro/overview

Resources

- Natural Resources Canada: **Tools and software for new buildings**
- http://www.nrcan.gc.ca/energy/efficiency/buildings/eenb/16596

- IBPSA: International Building Performance Simulation Association
- http://ibpsa.ca/

- Onebuilding.org: building performance forum
- http://onebuilding.org/index.html

- Energy Modeling Glossary
- https://energy-models.com/glossary

Conclusions

- Energy modelling is an extremely useful decision-making tool when deployed early and integrated fully into the design process.
- Energy modelling can reduce capital costs and ongoing maintenance and utility costs by optimizing the interactions between building components.
- It is much easier to incorporate needed changes when they are recognized through energy modelling early in the design process.
- If the project owner is considering solar power, energy modeling results can be used to optimize capacity.
- Beyond just choosing the right modeling software, the skills of an engineer or architect are paramount in order to make full use of energy modeling.
- “All models are wrong, but some are useful”

Questions?

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Introduction to Ground Source Heat Pump Systems

March 6, 2023

GEOptimize

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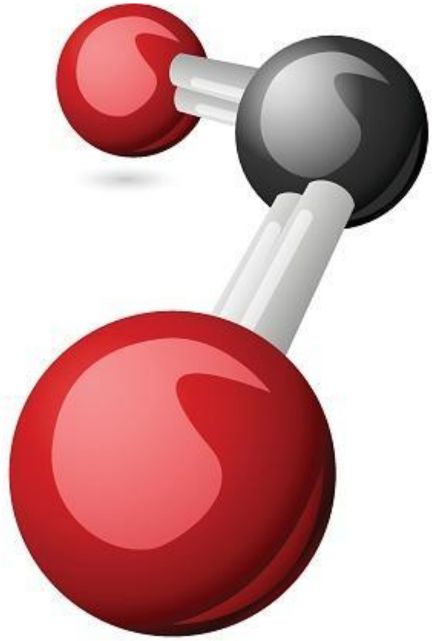
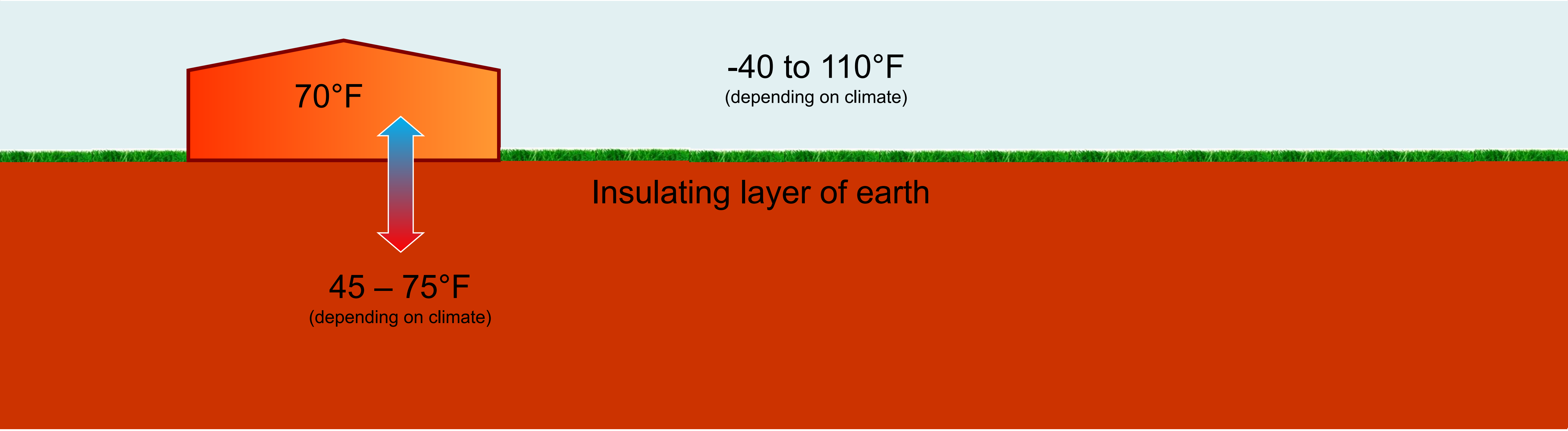
Ground source heat pump (GSHP) systems are perceived by many as:

- Expensive to install,
- Not very reliable
- Good for the environment - cut fossil fuels & reduce CO_2 emissions



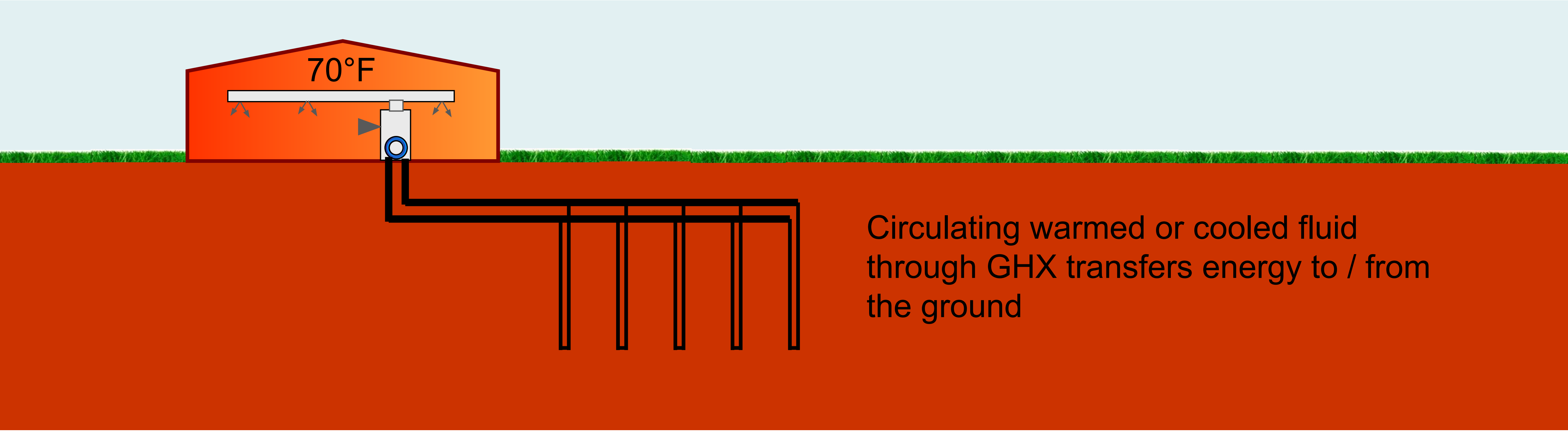
Ground stores energy we can use to heat / cool our buildings

- Constant temperature throughout the year
- Air temperature changes through the seasons

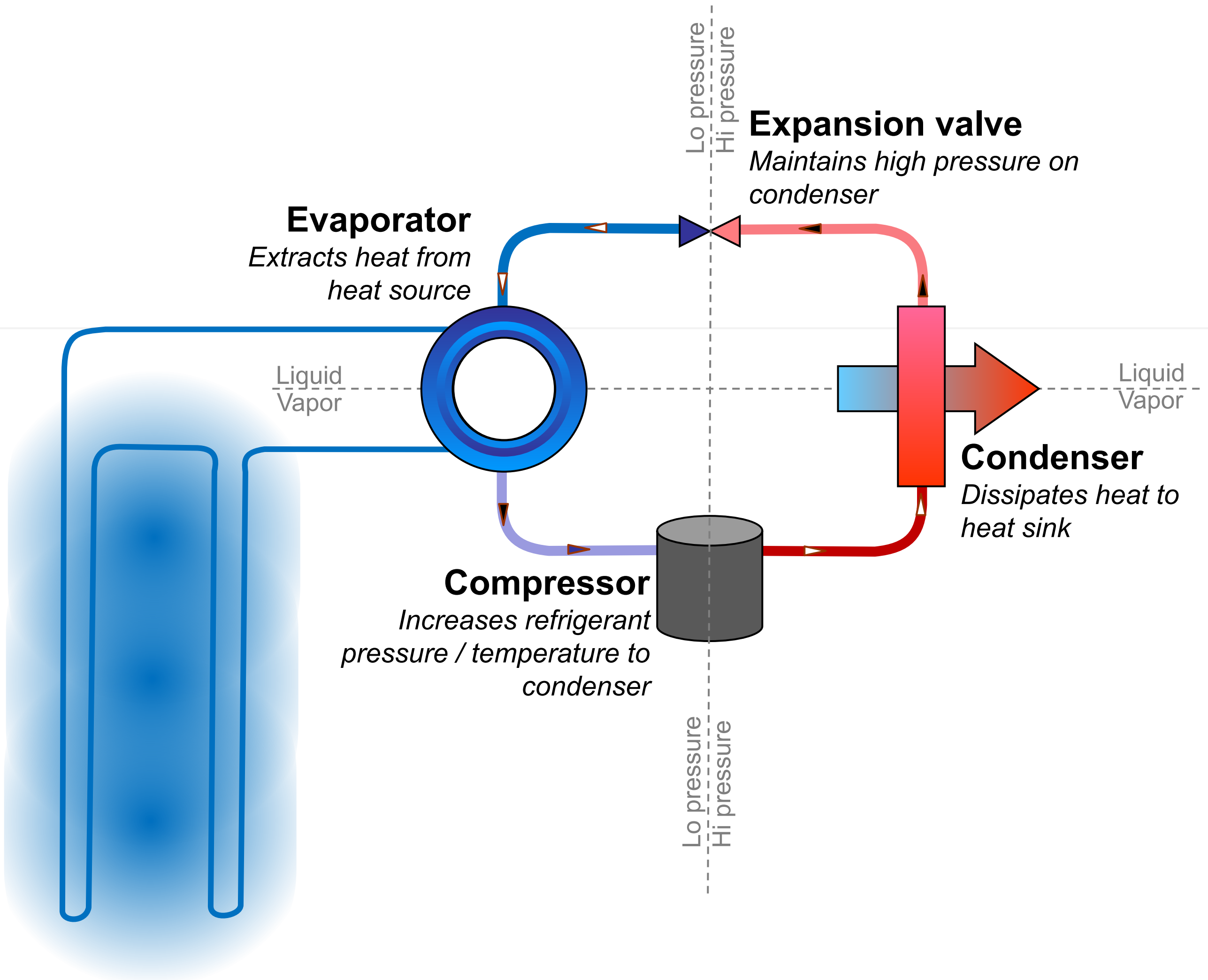


Ground heat exchanger (GHX) transfers energy to / from ground

- Circulating fluid cooled or warmed by heat pumps when heating or cooling the building creates a temperature difference between fluid in the pipe and the surrounding earth…transferring energy

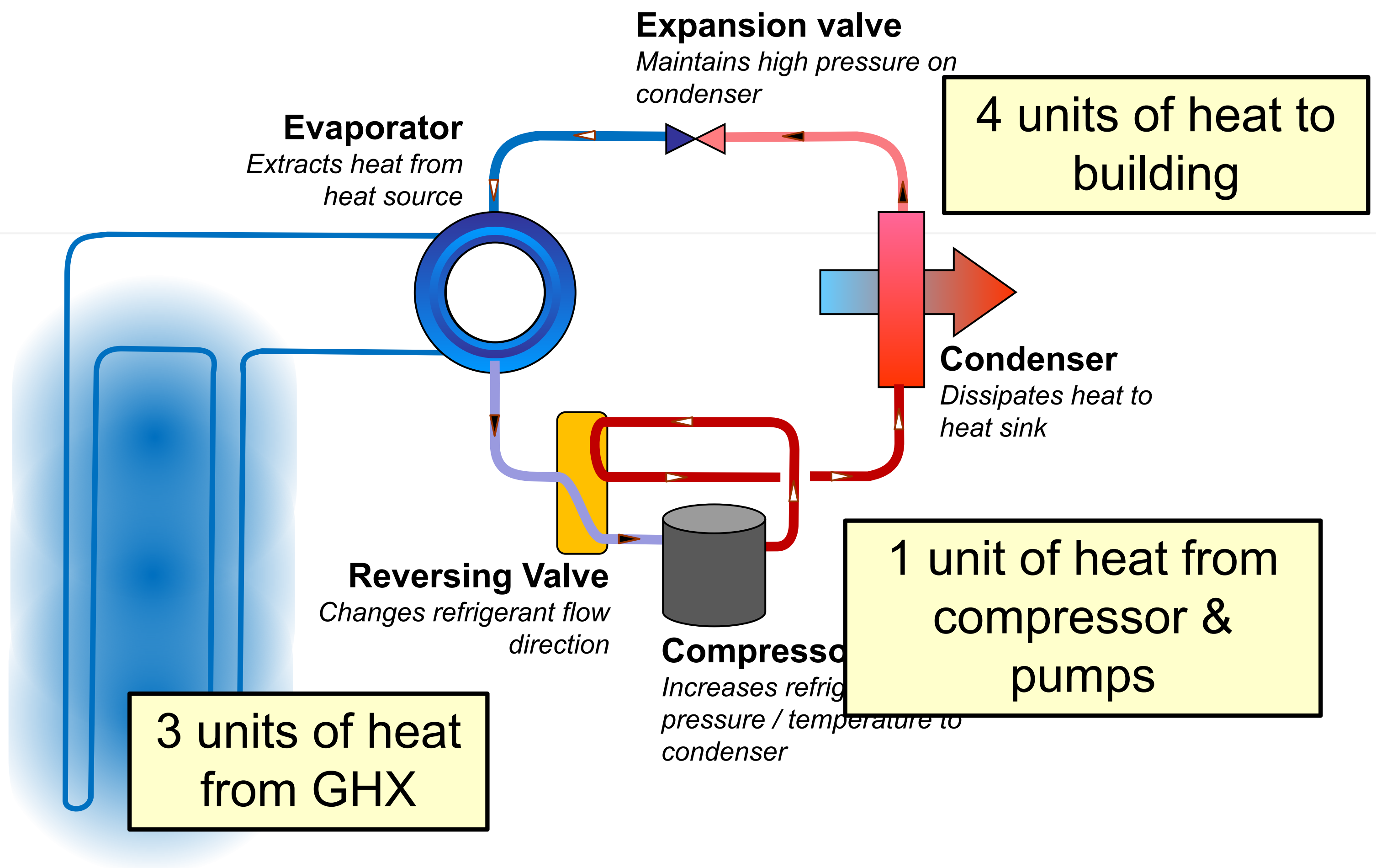


Basic heat pump components



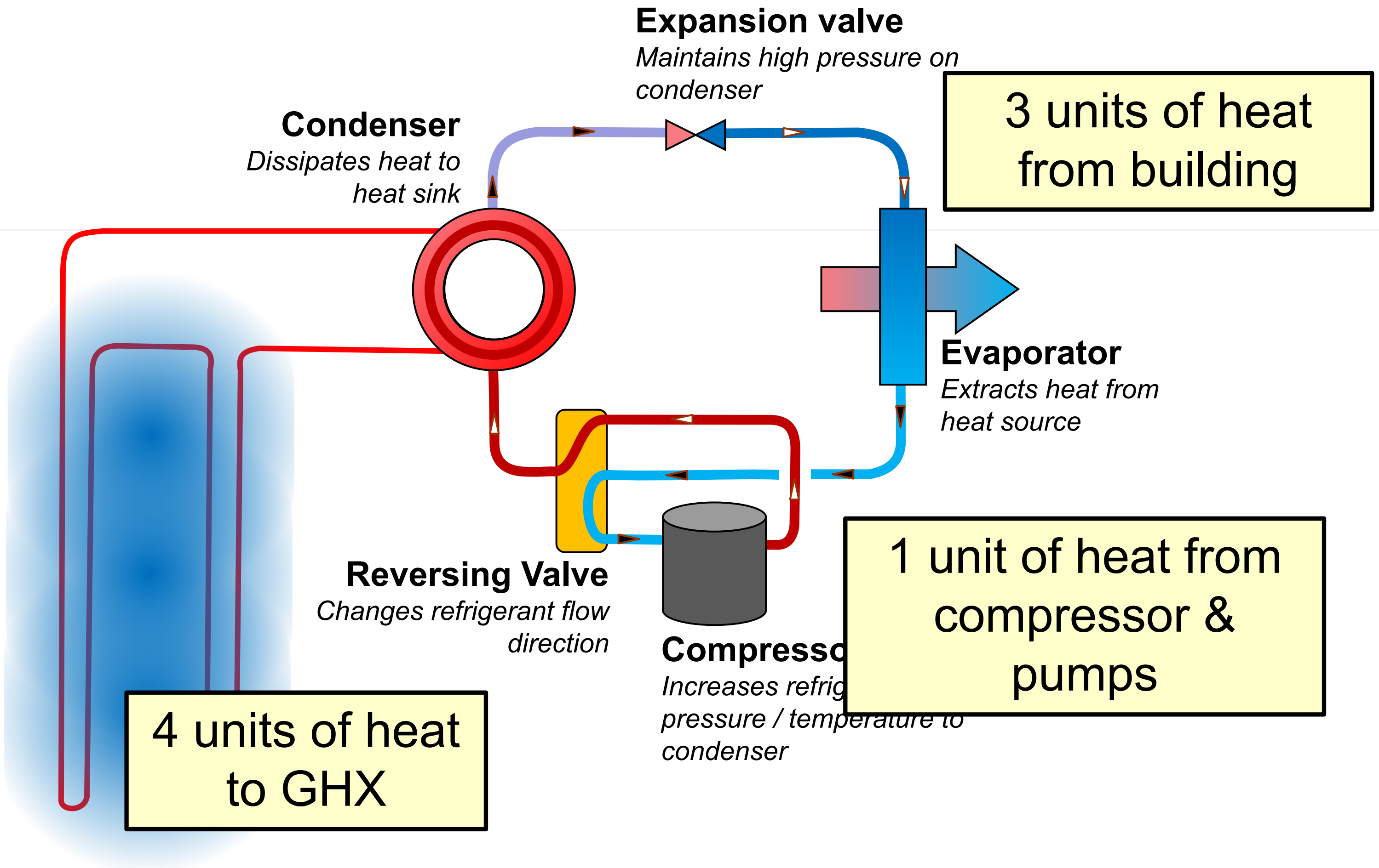
- Compressor: compresses refrigerant vapor…heated by increase in pressure
- Condenser: condenses refrigerant vapor into liquid…phase change transfers large amount of heat
- Expansion valve: maintains high pressure / temperature on discharge side of compressor
- Evaporator: boils droplets of liquid refrigerant at low pressure / temperature

Heat pump heating building



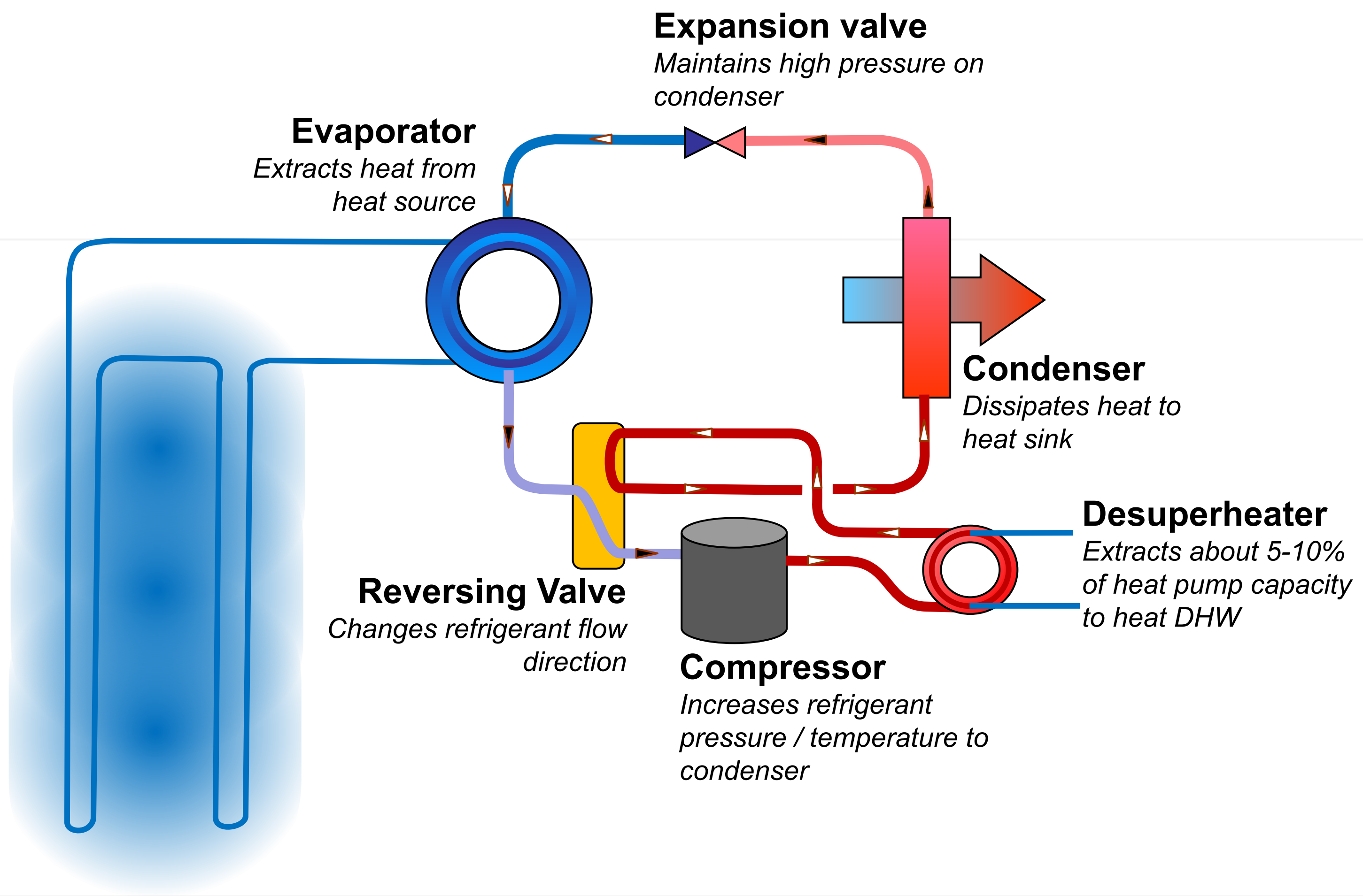
- Heat is extracted from fluid in GHX, vaporizing refrigerant
- Compressor draws in, compresses and heats refrigerant
- Hot refrigerant pushed through condenser, rejects heat to air in building

Heat pump cooling building



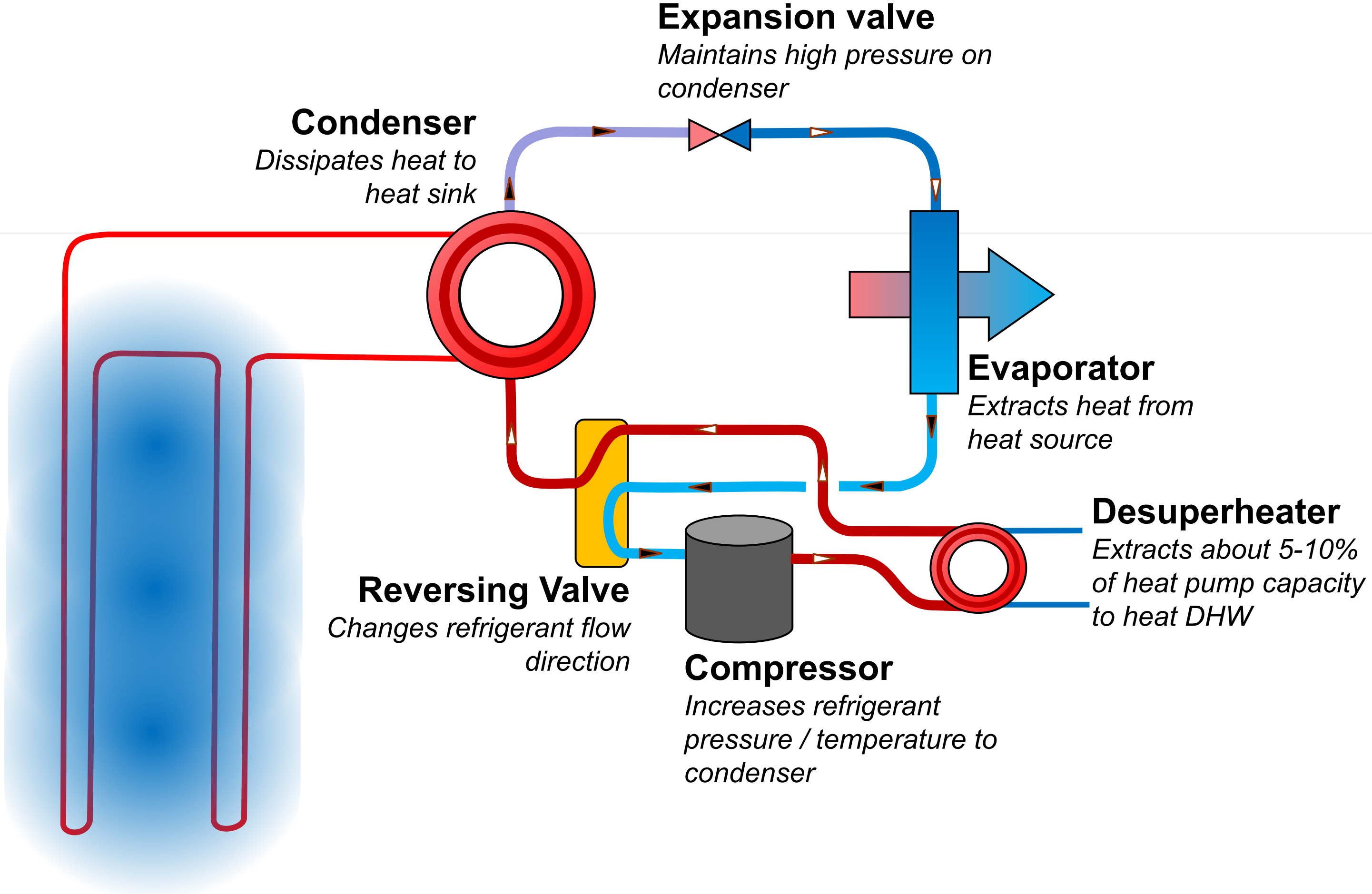
- Heat extracted from air in building, vaporizing refrigerant
- Compressor draws in, compresses and heats refrigerant
- Hot refrigerant pushed through condenser, rejects heat to fluid in GHX

Heat pump heating building with desuperheater



- Desuperheater is an added refrigerant to water heat exchanger connected to the discharge of the compressor…the hottest refrigerant in the system
- 5-10% of heat pump capacity is diverted to DHW tank when circulation pump to tank is operating
- Does not produce hot water when not heating or cooling

Heat pump cooling building with desuperheater

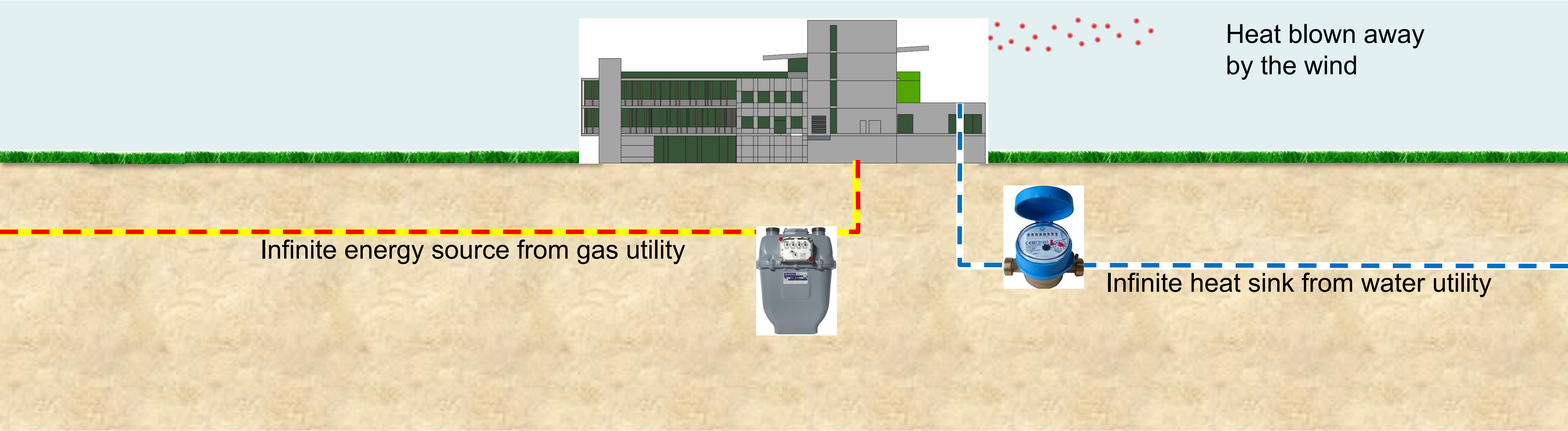


- DHW is heated if the heat pump is operating in heating mode or cooling mode
- Does not produce hot water when not heating or cooling

Fundamental difference in designing conventional HVAC system and GSHP system

Designing a conventional HVAC system

- Peak heating and cooling loads are all that is needed to design a conventional HVAC system
- Gas utility supplies energy as long as bills are paid
- Water utility supplies evaporative cooling…wind dissipates heat to air



Manufacturer's catalog data

Design and Operating Conditions		Water Distribution System Construction Materials	
Tower Type:	Counter Flow Induced Draft	Stand Pipe:	PVC
Water Flow Rate (GPM):	88 GPM	Sprinkler Head:	Nylon
Entering Water Temperature	95°F	Sprinkler Pipes:	PVC
Leaving Water Temperature	85°F	**Mechanical Equipment**	
Wet Bulb Temperature:	75°F	Fan Unit:	One Unit per Tower
Total Fan BHP:	1 HP	Type:	Axial Flow
Total Pump Head:	6.0'	Manufacturer:	CTS
Drift Loss of Water Flow:	0.1%	Diameter:	30.25"
Evaporation Loss of Water Flow:	0.93%	Blade Material:	Nylon
Design Wind Load:	30.7 lbs/sq. ft.	Hub Material:	Nylon
Structural Details		Nominal Air Volume:	8,100 CFM
Overall Diameter:	62.25"	**Fan Motor**	
Overall Height:	68 3/8"		
Dry Weight:	223 lbs.		
Operating Weight:	1,205 lbs.		
Basic Tower Construction Materials			
Tower Support Frame Assembly	FRP		
Casing:	FRP		
Casing Supporters	Nylon		
Cold Water Basin	FRP		
Filling:	PVC		
Filling Supports:	PVC		
Fan Guard	HDGS		
Mechanical Equipment Supports:	HDGS		
Inlet Louvers:	PVC		
Bolts, Nuts & Washers:	STS	Water Flow (GPM):	88 GPM

- Manufacturer designs cooling towers or air-cooled condensers to meet peak loads at peak design conditions.
- Designer only needs the peak cooling load to select a cooling tower from a website or catalog.

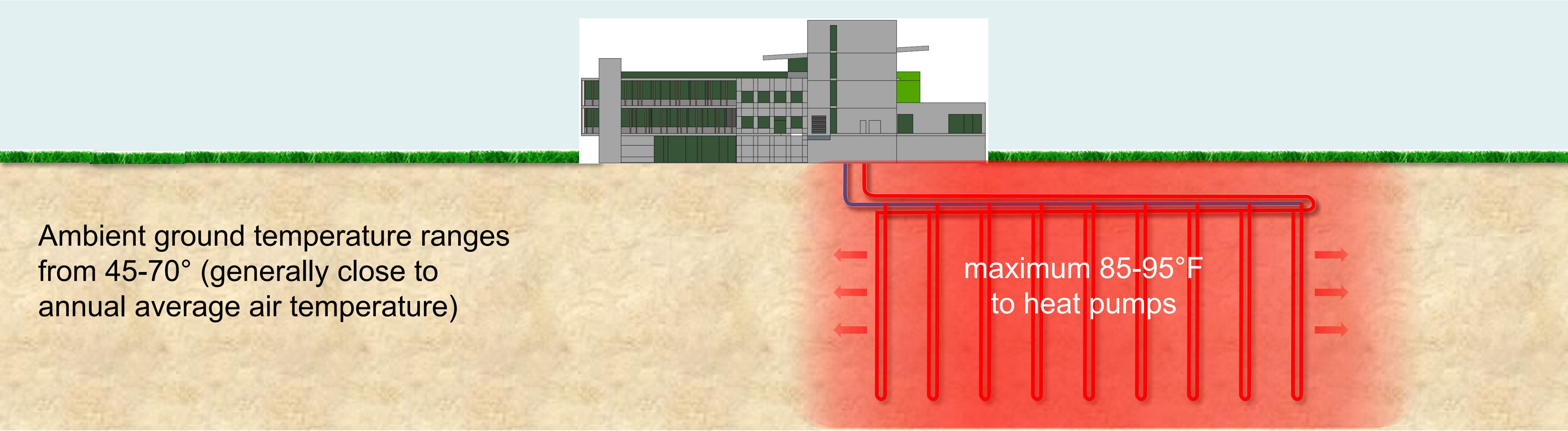
Gas utility pipe sizing tables

Inlet Pressure:	5 psig								
Pressure Drop:	0.5 psig								
Length (ft)	Calculated Flow (Natural Gas) (Cubic Feet of Gas Per Hour)								
	CTS		IPS						
Nom OD	1/2	1	3/4	1	1-1/4	1-1/2	2	3	4
DR	7	11.5	11	11	10	11	11	11.5	11.5
ID	0.436	0.918	0.848	1.062	1.308	1.534	1.917	2.855	3.670
10	481	3413	2771	5007	8672	13181	23704	67535	130791
20	331	2346	1904	3442	5960	9059	16292	46416	89892
30	266	1884	1529	2764	4786	7275	13083	37274	72186
40	227	1612	1309	2365	4096	6226	11197	31902	61782
50	202	1429	1160	2096	3631	5518	9924	28274	54756
60	183	1295	1051	1899	3290	5000	8992	25618	49613
70	168	1191	967	1747	3026	4600	8272	23568	45643
80	156	1108	899	1626	2815	4279	7696	21926	42462
90	147	1040	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	39841
100	139	982	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	37634
125	123	870	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	33354
150	111	789	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30221
175	102	726	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	27803
200	95	675	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25865
250	84	598	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22924
300	76	542	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20771
350	70	499	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19109
400	65	464	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17777
450	61	435	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16680
500	58	411	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15756
600	53	373	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14276
700	48	343	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13133
800	45	319	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12218
900	42	299	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11464
1000	40	283	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10829
1500	32	227	184	333	577	876	1576	4490	8696
2000	27	194	158	285	493	750	1349	3843	7443

- Gas utility provides tables to select gas pipe size needed for selected equipment.
- Designer only needs peak heating load to size the energy source.

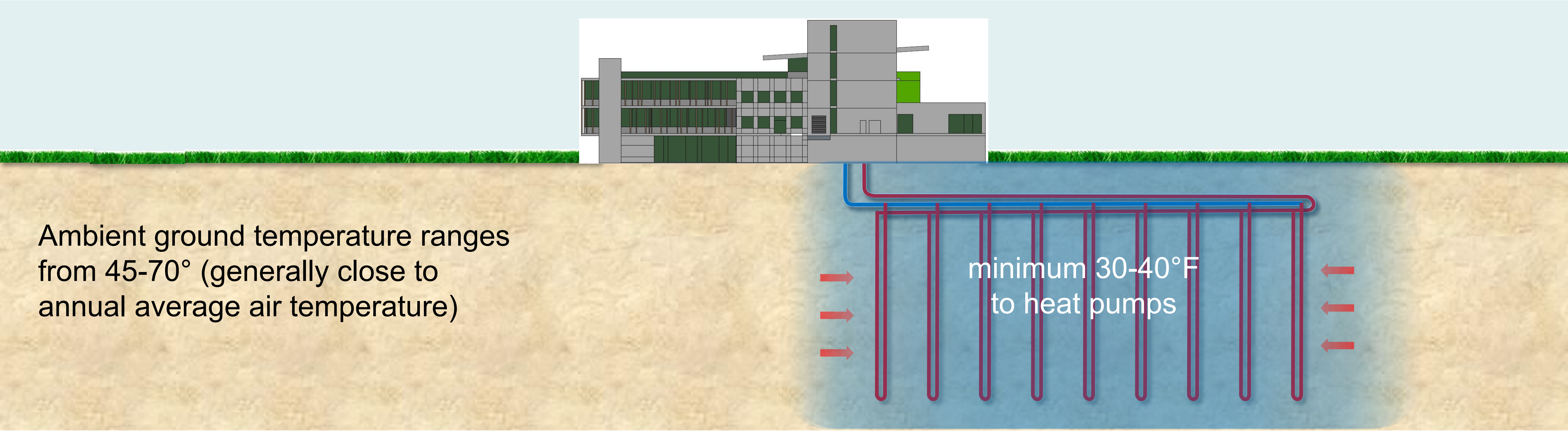
Heat rejected to ground when building is **cooled**

- Earth surrounding GHX piping warms when cooling building
- Heat slowly dissipates to surrounding earth
- Earth conducts heat poorly and temperature will increase over time
- Typically designed to deliver maximum 85-95°F fluid to heat pumps



Heat extracted from ground when building is **heated**

- Earth surround GHX piping cools when heating building
- Heat slowly conducted from surrounding soil to colder earth around GHX
- Most systems designed to deliver minimum 30-40°F fluid to heat pumps



Many methods of transferring energy to and from the ground

- A GHX cannot be selected from a website or supplier catalog…**it must be designed by the GSHP system designer** to supply and absorb energy from the building for the year and for the life of the building.





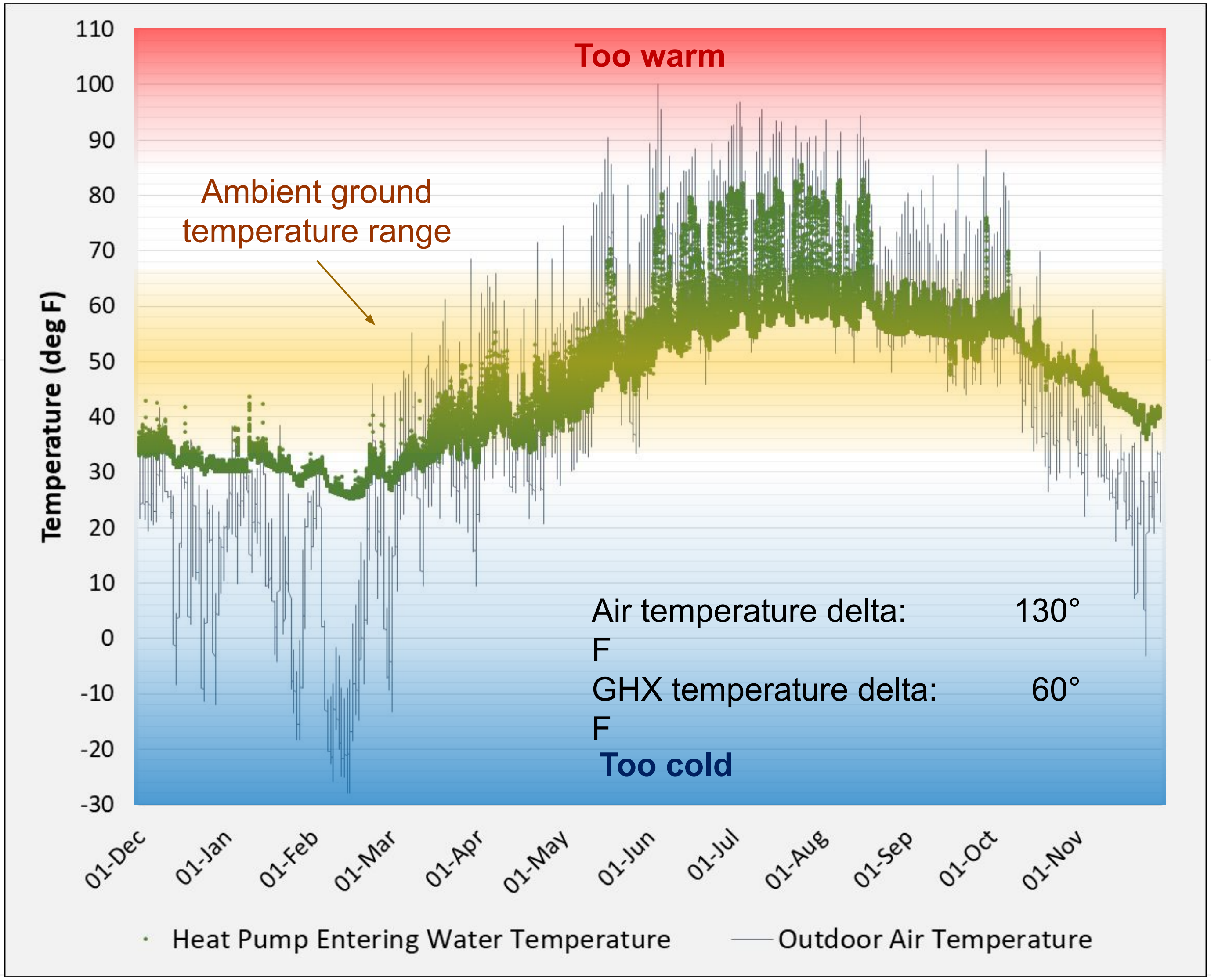
Transferring energy through man-made structures

- Pipe embedded in structural piles
- Pipe built into concrete tunnel walls
- Pipe integrated into wastewater pipes

For building owners, it's all about the money!

- Energy cost savings
- Reduce environmental impact

Ground is consistent energy source / heat sink



- GSHP systems are efficient because of stable ambient ground temperatures – about 45° - 70°F across N. America
- GHX designed to deliver water temperatures to heat pumps from 30° - 90°F
- Outdoor air temperatures range from -30° - 100°F

Rules of thumb are dangerous for GHX design

Common “Rules of thumb” in HVAC design

- Used to estimate proposed building heating and cooling loads
- Used to estimate size and cost of a GHX

- The size, cost & performance of a GHX is site and building specific.

Capacity: 400 square feet / ton

GHX: 200 feet of borehole / ton

Peak loads alone don’t determine size of GHX

- Peak cooling loads for 3 buildings are – 140 kW (480 kBtu/hr or 40 tons)
- Peak heating loads are identical – 113 kW (385 kBtu/hr)

Monthly energy load profiles

- Peak heating and cooling loads (kBtu/hr) are identical for 3 buildings
- Annual energy loads (kBtu) are much different
- Energy to and from GHX…annual cooling / heating ratio changes

Church

	Clg kBtu	Clg kBtu/hr	Htg kBtu	Htg kBtu/hr
Jan	3820	8	189734	385
Feb	6202	[illegible]	[illegible]	[illegible]
Mar	12177	[illegible]	[illegible]	[illegible]
Apr	16800	216	36614	170
May	24640	367	[illegible]	[illegible]
Jun	46285	446	[illegible]	[illegible]
Jul	52680	480	886	0
Aug	49068	465	[illegible]	[illegible]
Sep	38560	314	[illegible]	[illegible]
Oct	13821	121	24702	137
Nov	7571	62	98784	298
Dec	4884	10	176775	348
	276508	480	765455	385
Annual Cooling / Heating Ratio:				2.8 to 1

Retail

	Clg kBtu	Clg kBtu/hr	Htg kBtu	Htg kBtu/hr
Jan	19906	93	89734	385
Feb	[illegible]	[illegible]	[illegible]	[illegible]
Mar	[illegible]	[illegible]	[illegible]	[illegible]
Apr	40866	235	16614	110
May	[illegible]	[illegible]	[illegible]	[illegible]
Jun	[illegible]	[illegible]	[illegible]	[illegible]
Jul	102358	480	0	0
Aug	[illegible]	[illegible]	[illegible]	[illegible]
Sep	[illegible]	[illegible]	[illegible]	[illegible]
Oct	[illegible]	[illegible]	[illegible]	[illegible]
Nov	41571	135	36784	251
Dec	27884	102	76775	331
	682463	480	341869	385
Annual Cooling / Heating Ratio:				1

Apartment

	Clg kBtu	Clg kBtu/hr	Htg kBtu	Htg kBtu/hr
Jan	5560	25	159734	385
Feb	[illegible]	83	112120	360
Mar	[illegible]	185	71304	305
Apr	28866	260	30614	155
May	[illegible]	329	11152	60
Jun	[illegible]	423	8545	45
Jul	92358	480	7650	43
Aug	[illegible]	447	7550	45
Sep	[illegible]	360	8479	53
Oct	[illegible]	169	18702	132
Nov	[illegible]	79	66784	269
Dec	6570	22	126775	340
	437765	480	629409	385
Annual Cooling / Heating Ratio:				0.7 to 1

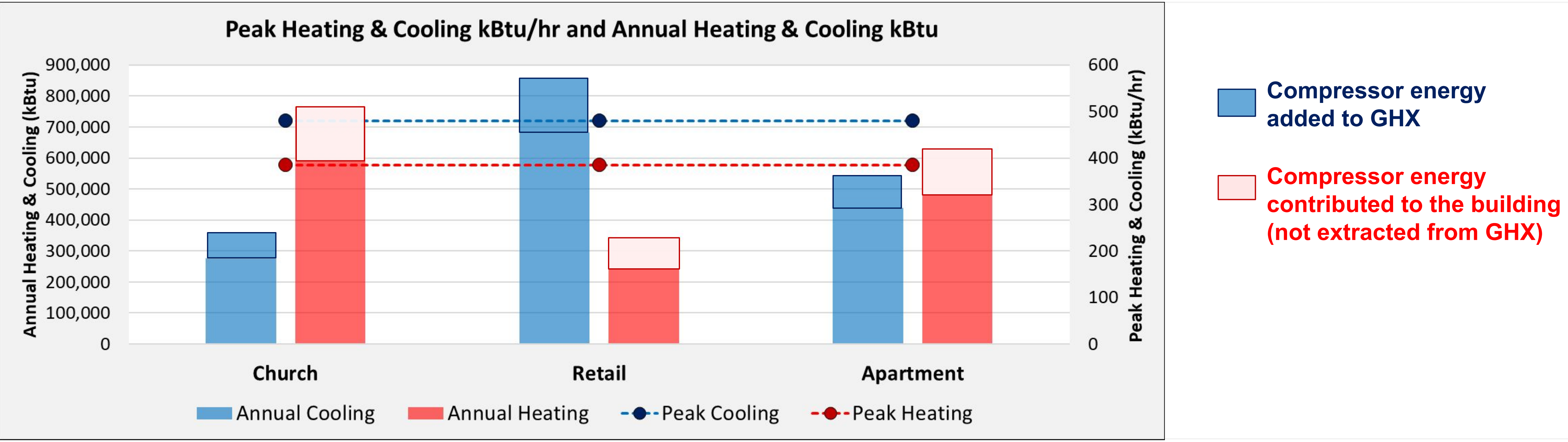
276508 480 765455 385

682463 480 341869 385

437765 480 629409 385

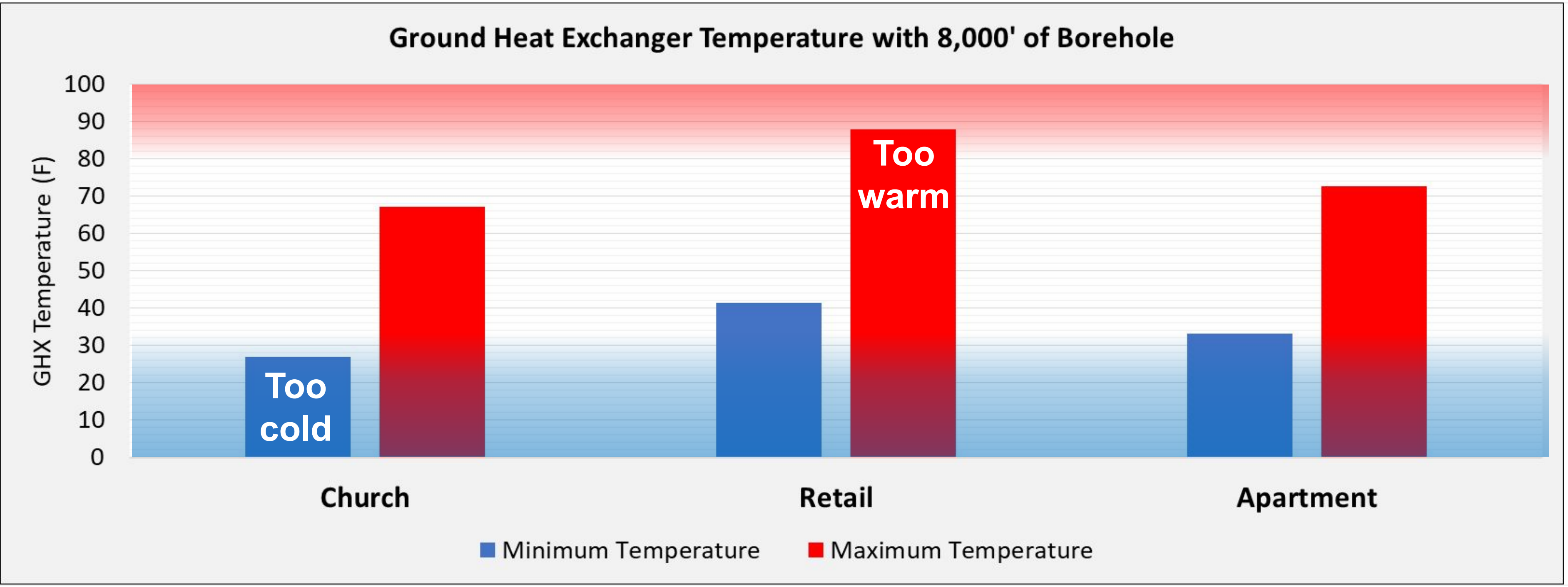
Energy rejected to ground versus energy extracted from ground

- Peak heating & cooling loads identical for each building
- Total annual heating and cooling loads much different
- Compressor energy adds heat to GHX in cooling, provides heat to building when heating



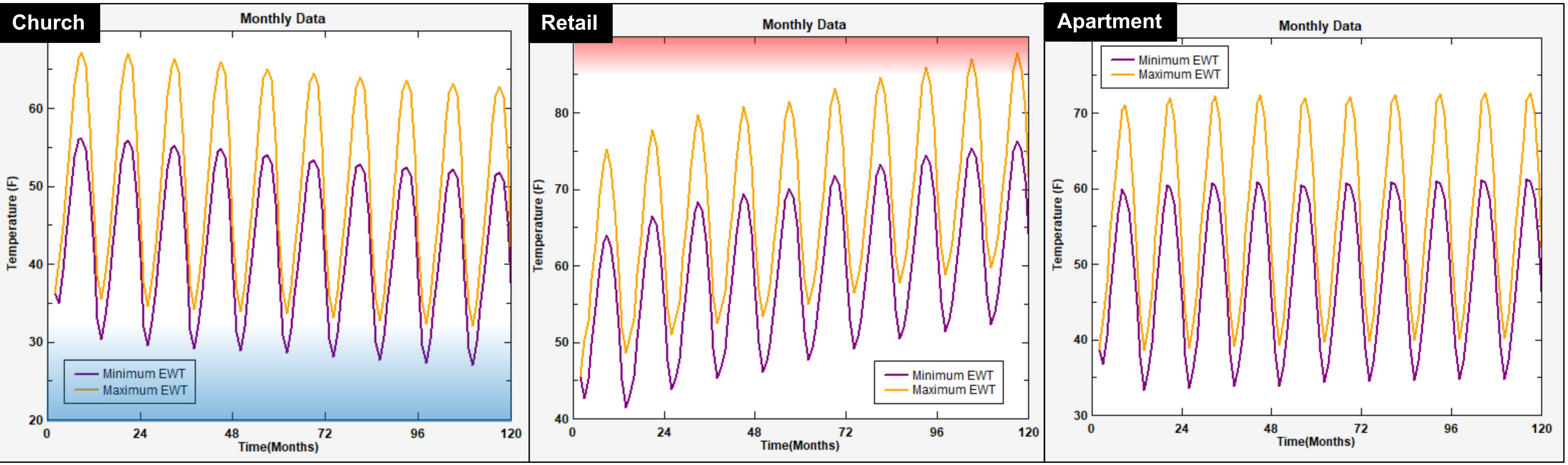
Rules of thumb suggest these buildings need 8,000' of borehole

- Max / min temperatures should be 32-40°F / 85-90°F for efficient heat pump operation.
- Potential for heat pumps to quit working if temperature too high or low



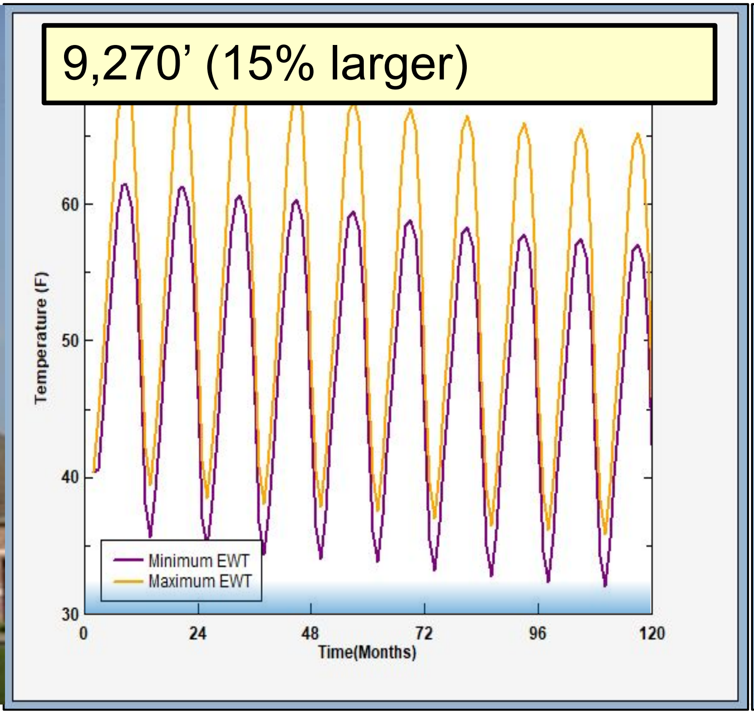
Rules of thumb don't consider all the variables

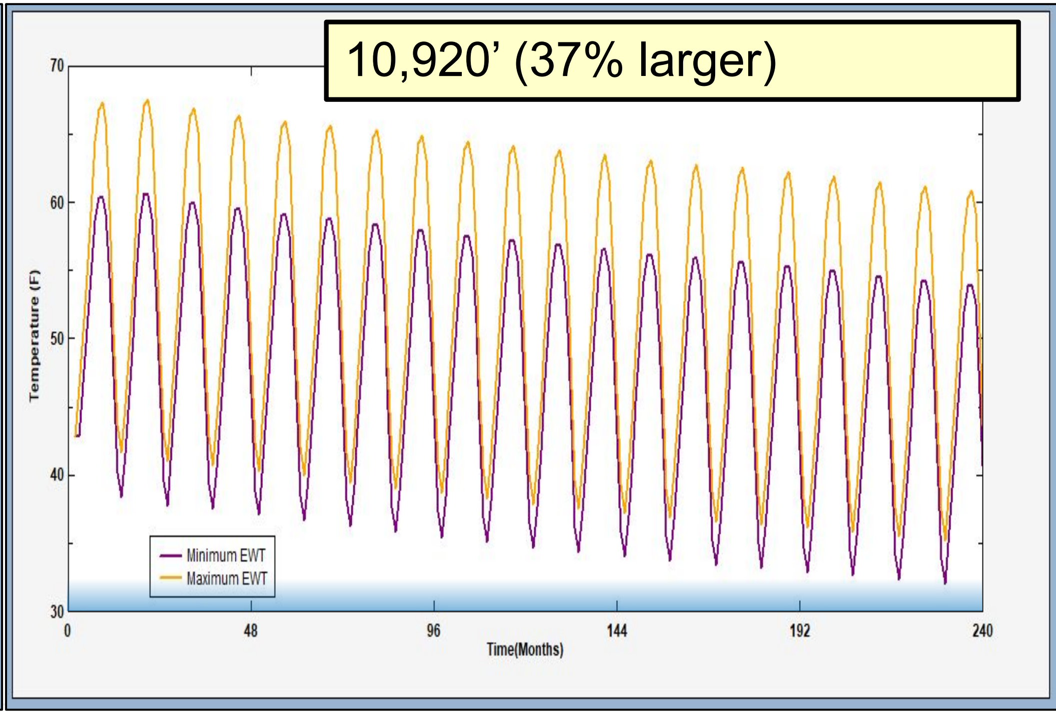
- After 10 years GHX temperature for church and retail store fall outside efficient operating parameters.
- Balanced loads of apartment building maintains efficient operating temperatures over time



Increasing size of GHX for church

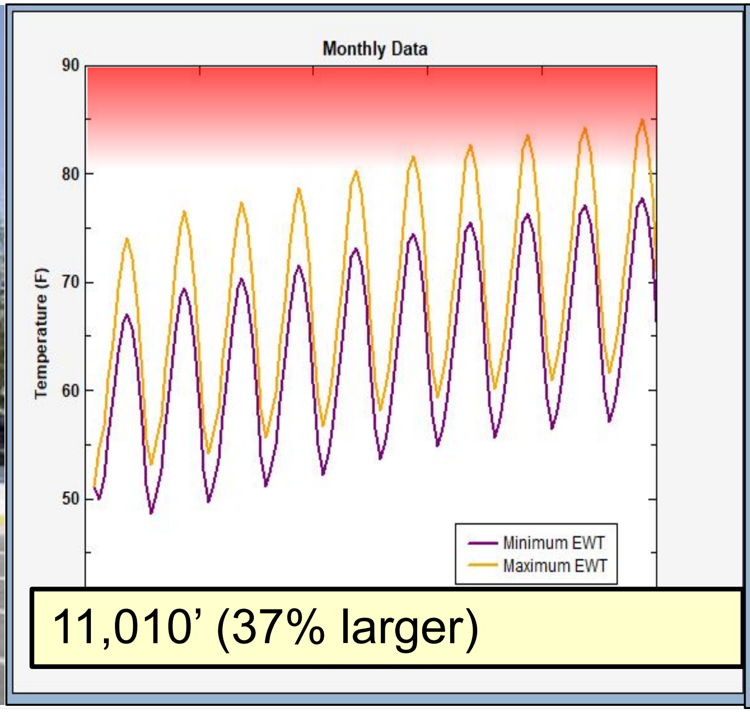
- A larger GHX extends the time till the temperature of the GHX drops below efficient operating parameters…but only delays the inevitable!



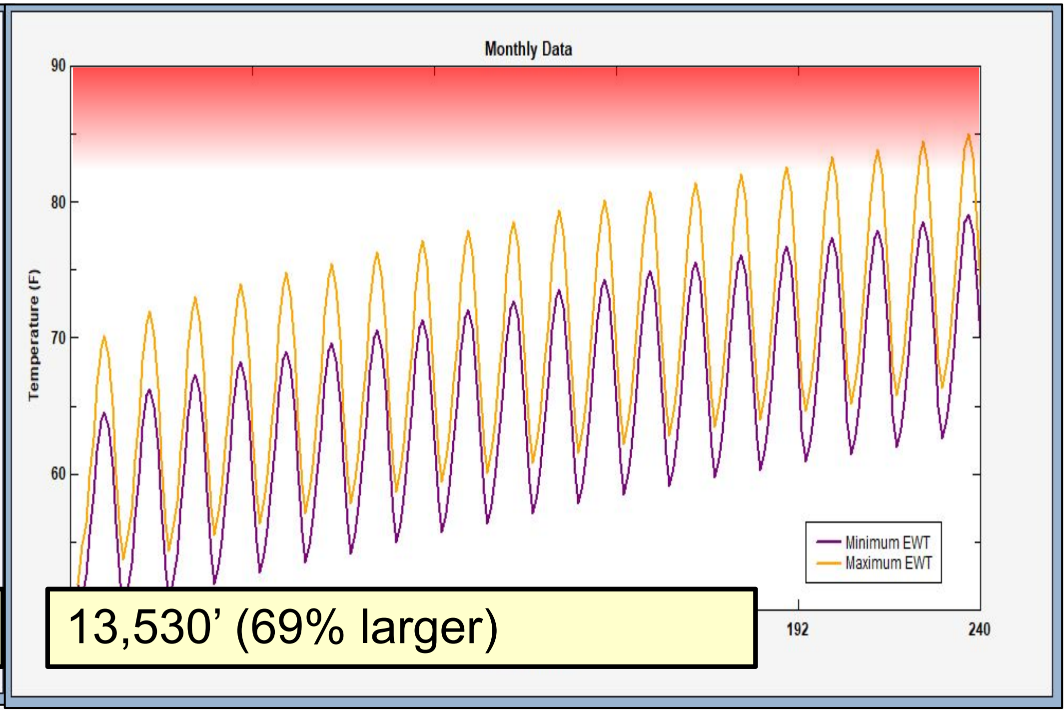


Increasing size of GHX for retail

- Increasing the size of the GHX extends the time till the temperature increases outside of efficient operating parameters…but doesn’t prevent long term temperature degradation



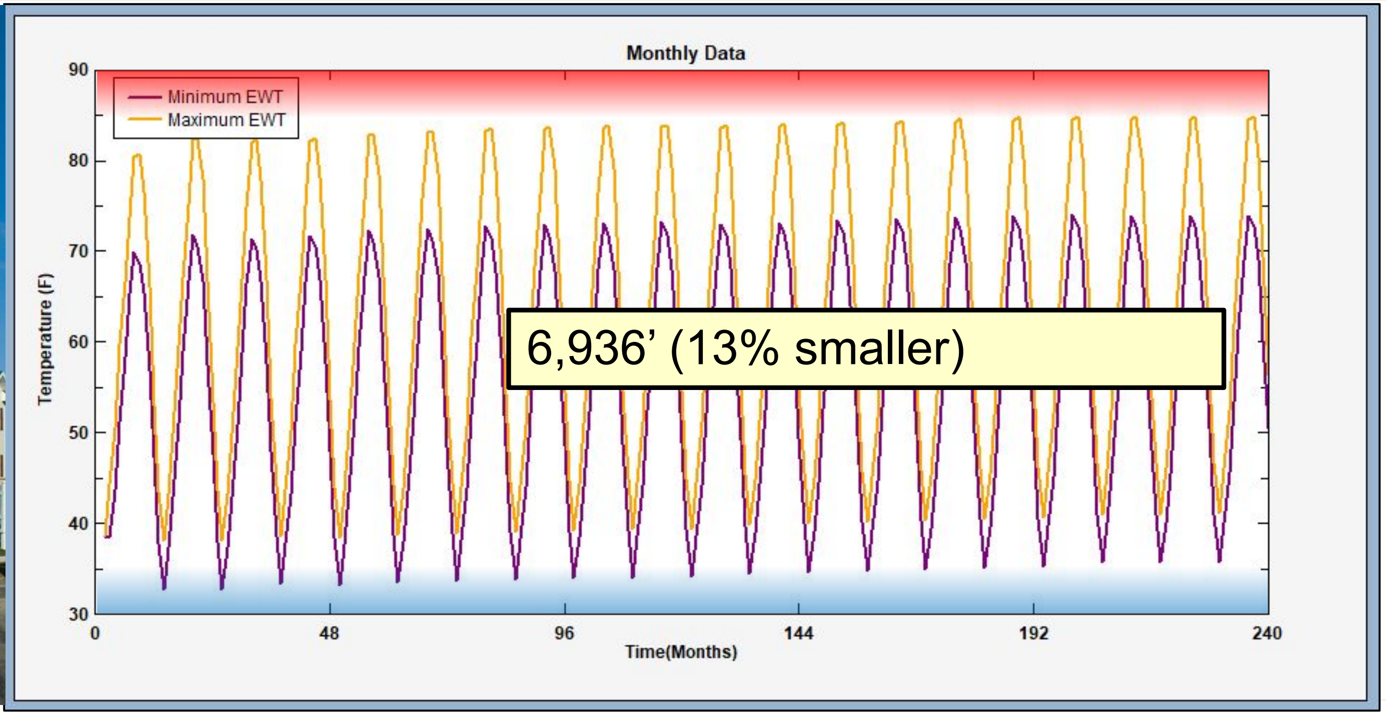
11,010’ (37% larger)



13,530’ (69% larger)

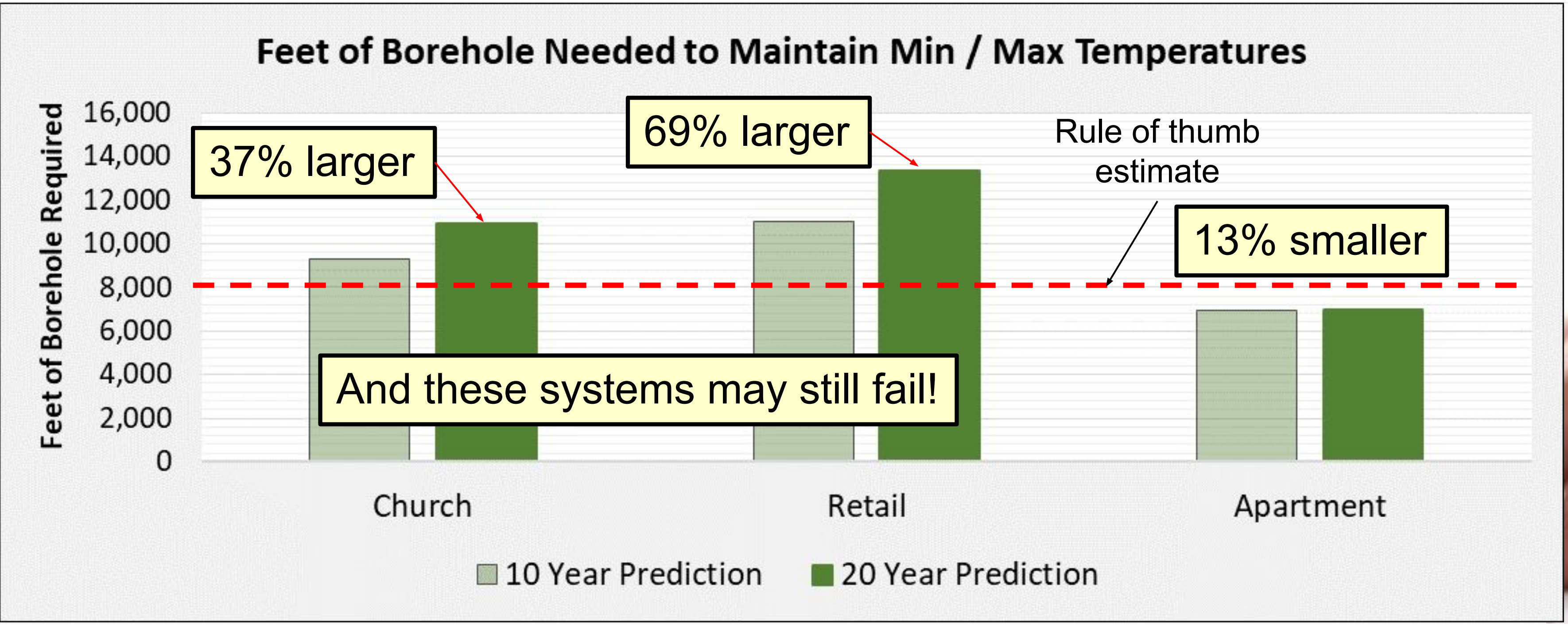
Reducing size of GHX for apartment

- Proper design reduces the amount of drilling required from 8,000 ft to less than 7,000 ft (13% cost savings)
- Balancing energy loads allows the system to operate efficiently for the life of the building

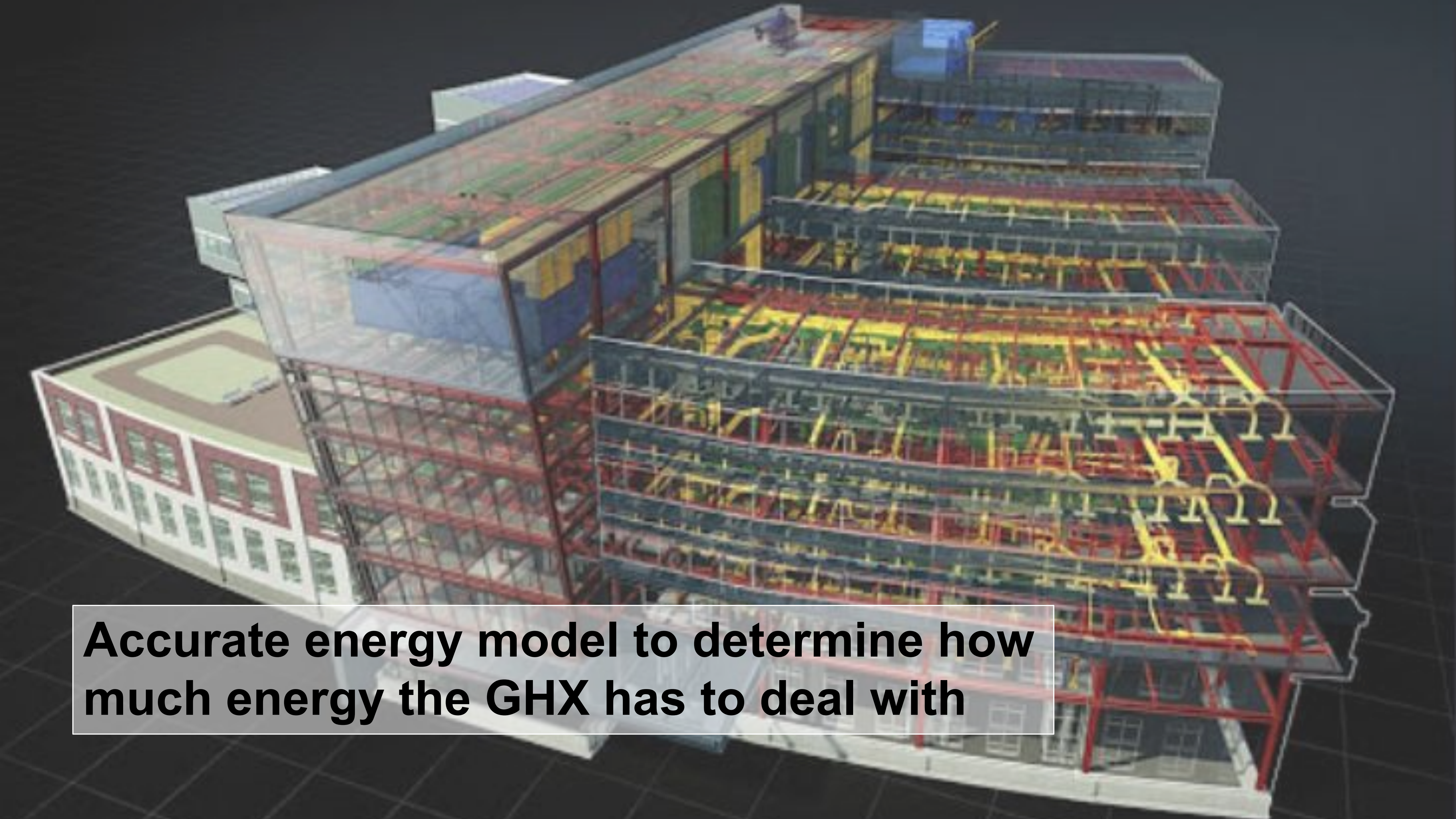


Rules of thumb can result in projects that either:

- Fail because of long term temperature degradation, or
- Are not built because they are too expensive to build



Balancing loads improves performance and reduces cost



Accurate energy model to determine how much energy the GHX has to deal with

GHX and borehole design considerations

Soil properties

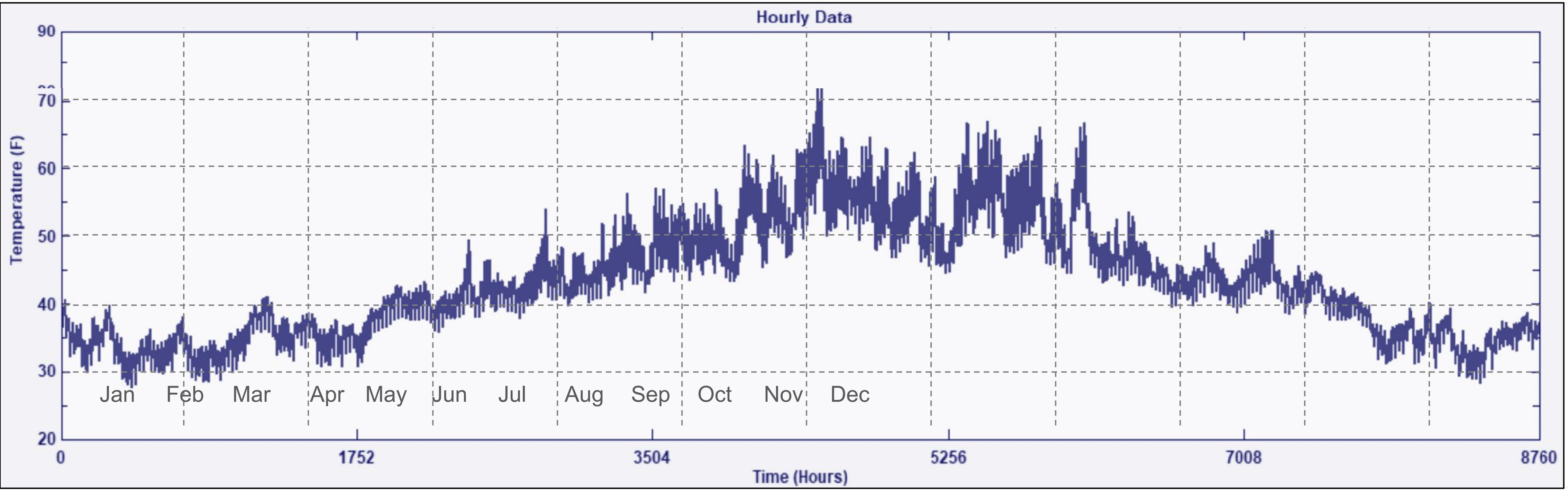
- Soil properties determine how much and how quickly energy can be transferred to and from the ground surrounding GHX piping

Borehole design

- Borehole diameter, pipe and grout specifications and pipe placement in the borehole impact the performance of a GHX

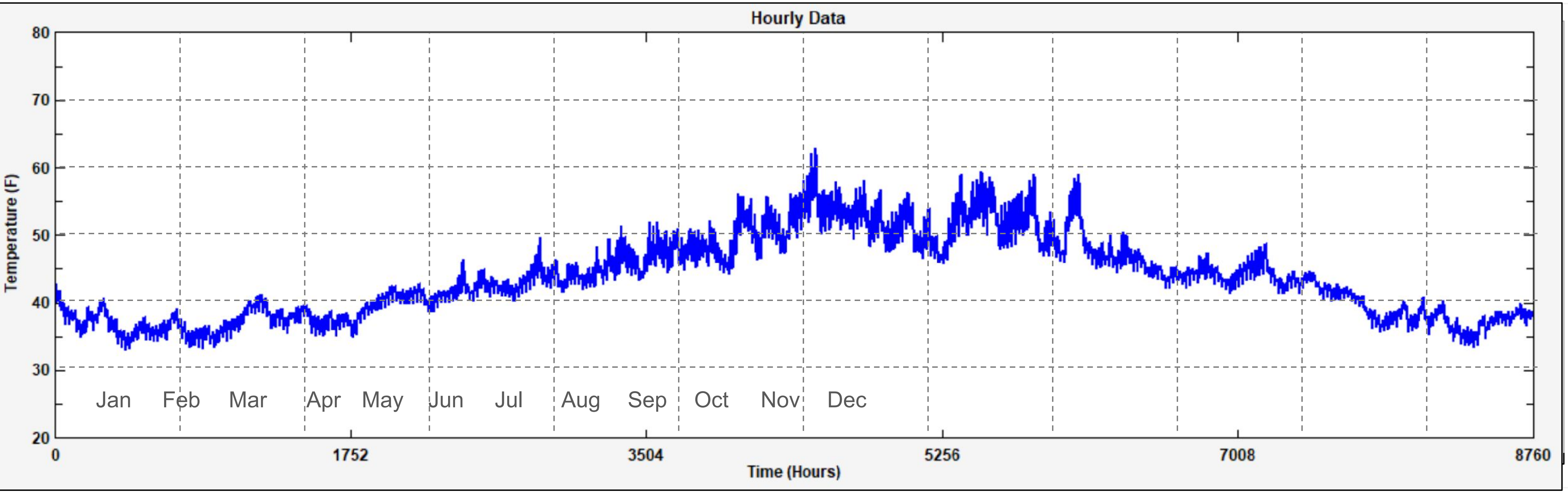
Typical annual GHX temperature profile

- Temperature profile of GHX with standard grout (TC – 0.40 Btu/hr * ft * °F
  - Temperature range: 26°F to 73°F



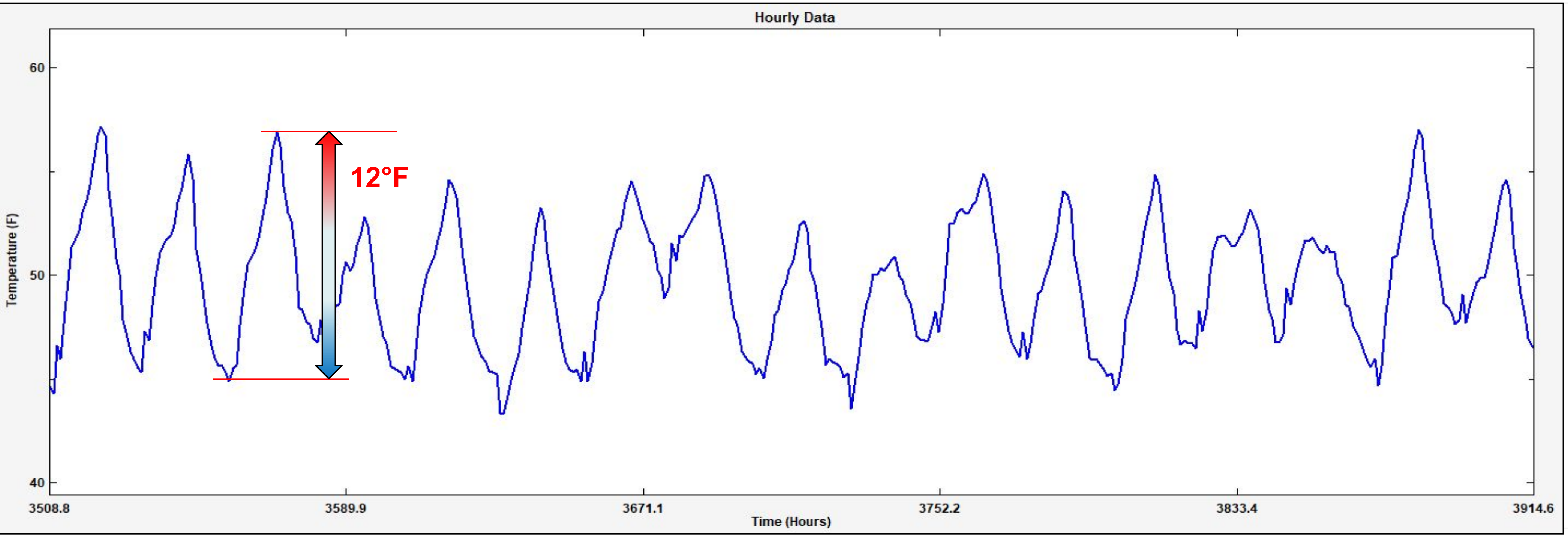
Typical annual GHX temperature profile

- Profile with thermally enhanced grout (TC – 1.20 Btu/hr * ft * °F
  - Temperature range: 34°F to 63°F



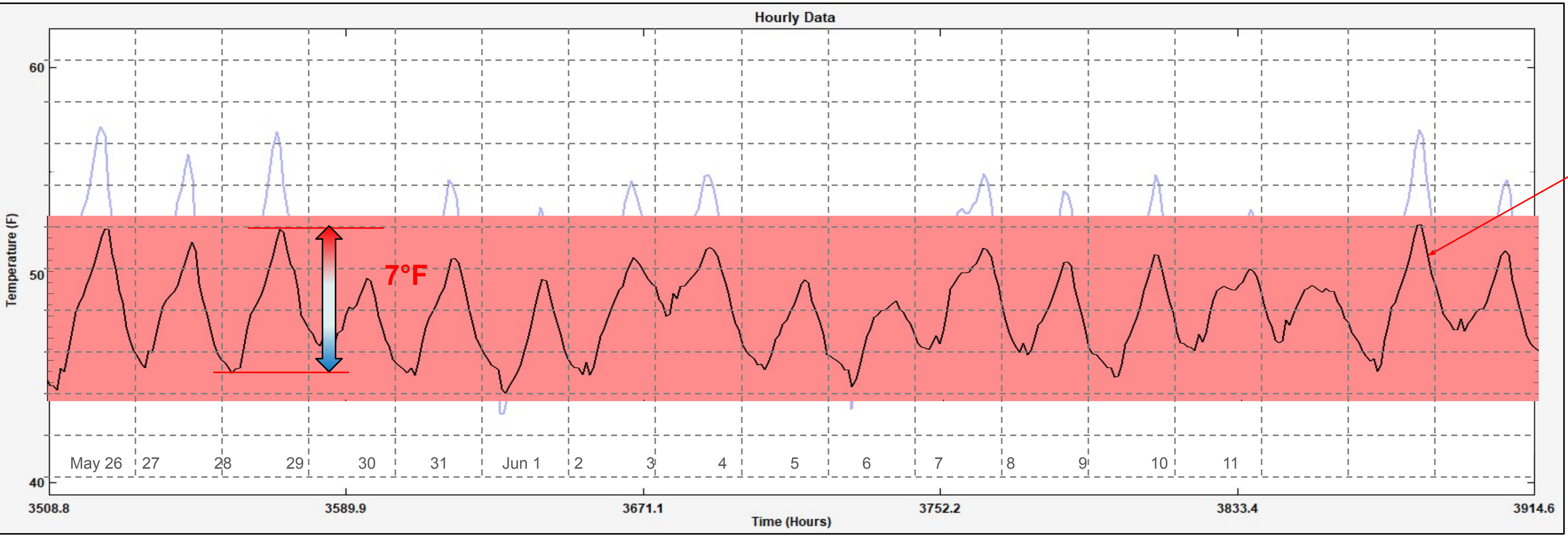
Impact of borehole design on daily temperature profile

- Standard grout has conductivity of about 0.40 Btu/hr * ft * °F
- Resists to heat transfer from GHX to surrounding earth



Thermally enhanced grout in boreholes reduces daily temperature range

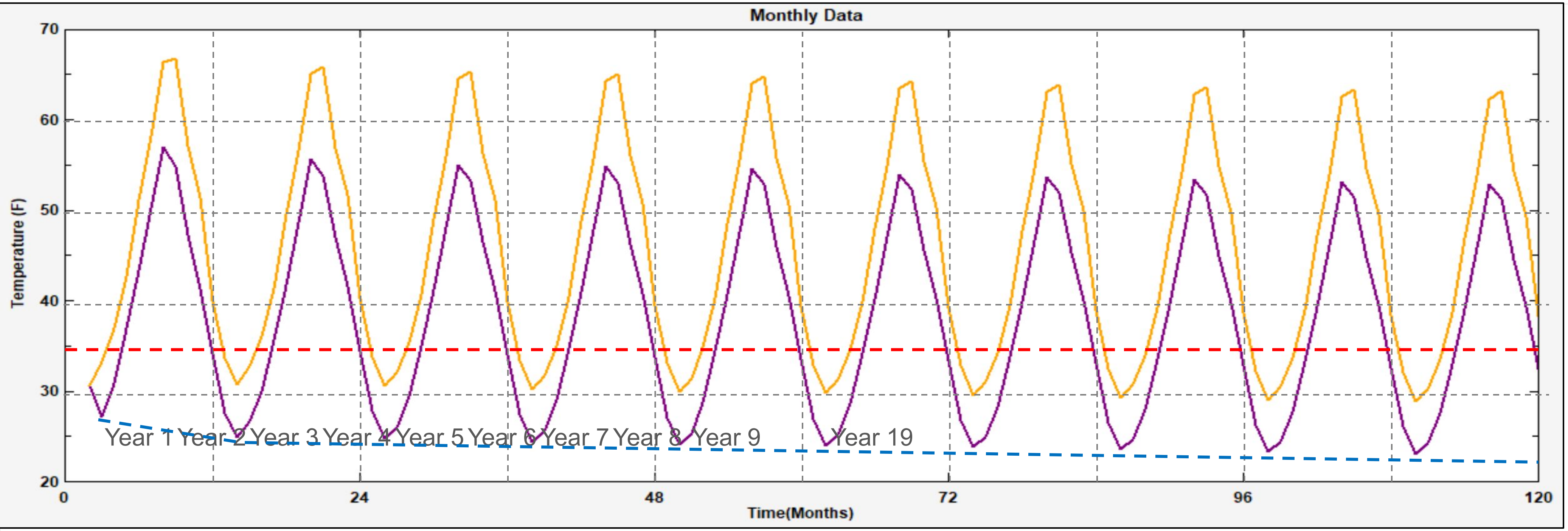
- Surrounding U-tube with thermally enhanced grout allows heat to transfer more quickly to surrounding earth
  - Lowers temperatures to heat pump when cooling
  - Increases temperatures to heat pump when heating



EWT to heat pump with thermally enhanced grout

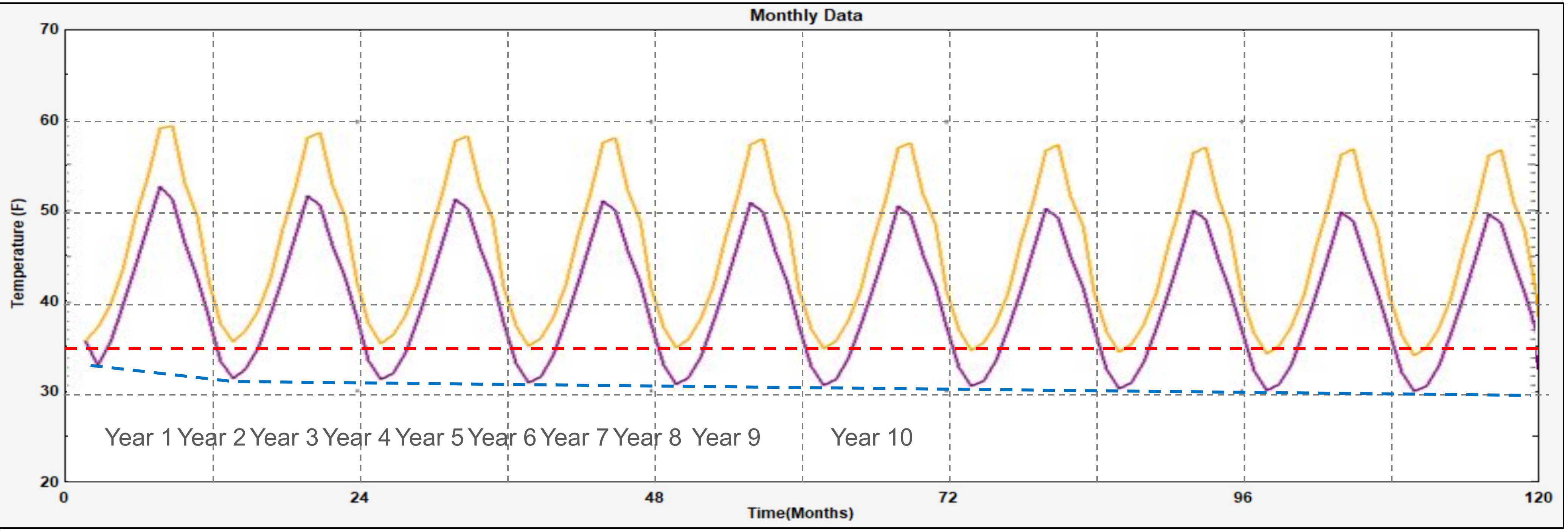
Typical 10 year temperature profile with 32 boreholes

- Project slightly heating dominant…temperature drops about 0.2°F / year
- After 10 years minimum temperature 24°F



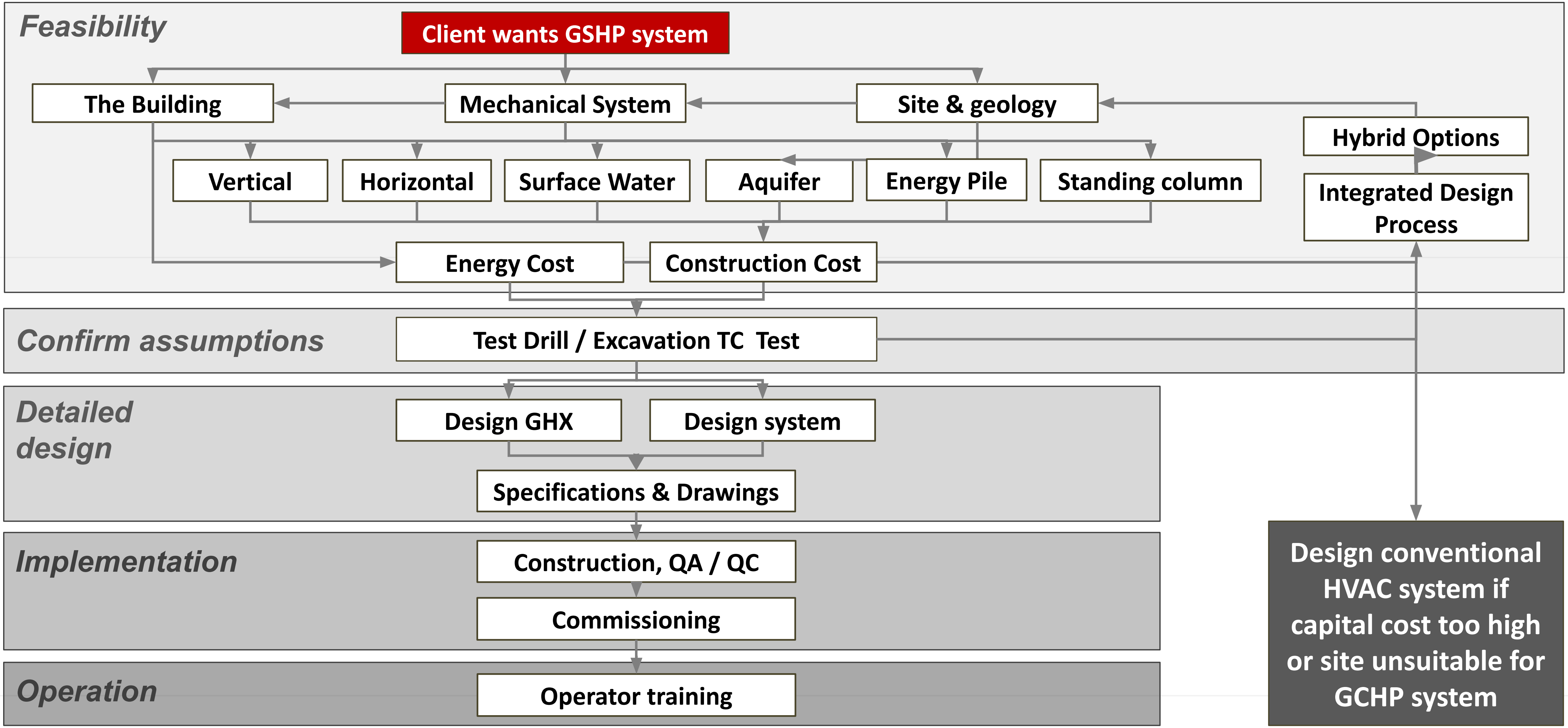
Typical 10 year temperature profile with 48 boreholes

- Still heating dominant - minimum temperature after 10 years 30°F
- Adding more boreholes only defers long-term temperature degradation
- More heat rejection (cooling) and / or less extraction (heating) will stop will stop long term temperature degradation

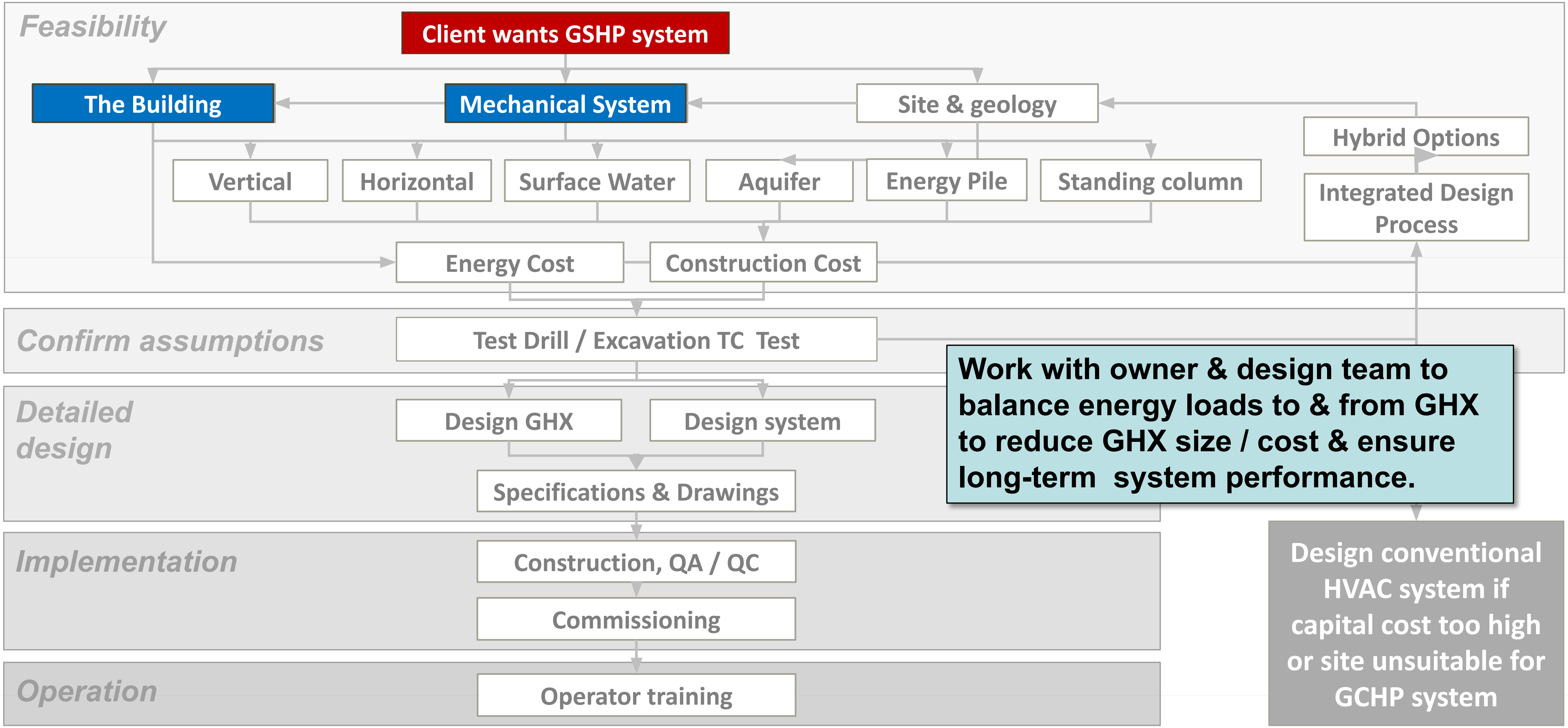


Where do you start when your client wants a GSHP system?

Design methodology flowchart



Determine how much energy GHX has to deal with



Changing energy loads with glass

- Less glass or more, clear or reflective of shaded glass
- Daylighting and occupancy controls
- Provide owner / architect with implications of their design on size, cost and performance of a GHX




Optimizing building mechanical systems

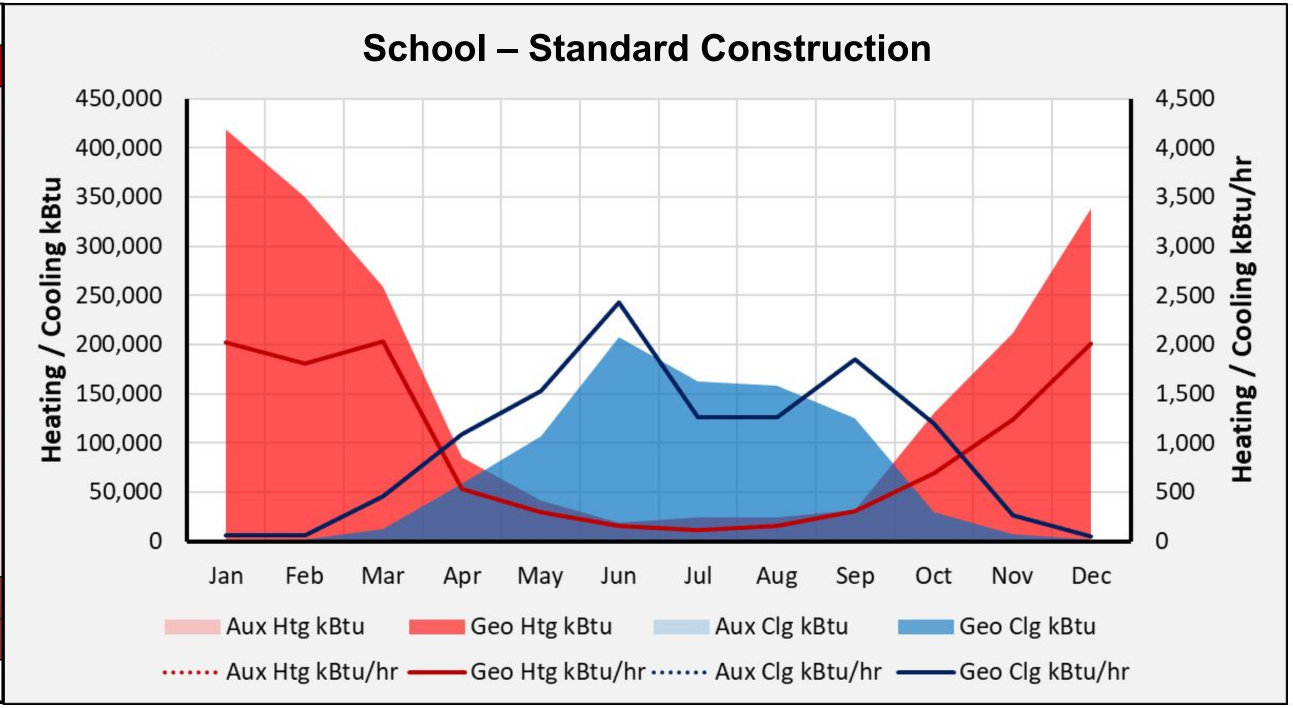
- Ventilation air strategy – direct outside air, demand ventilation, ERV
- Heat pump selection – heat pump efficiency and type
- Distribution design temperatures – low hot water, high chilled water
- Piping system design and pump power – flow rates, pressure drop




Initial energy model

- School in this climate zone is heating dominant…will extract more energy from GHX when heating than will be rejected to GHX when cooling

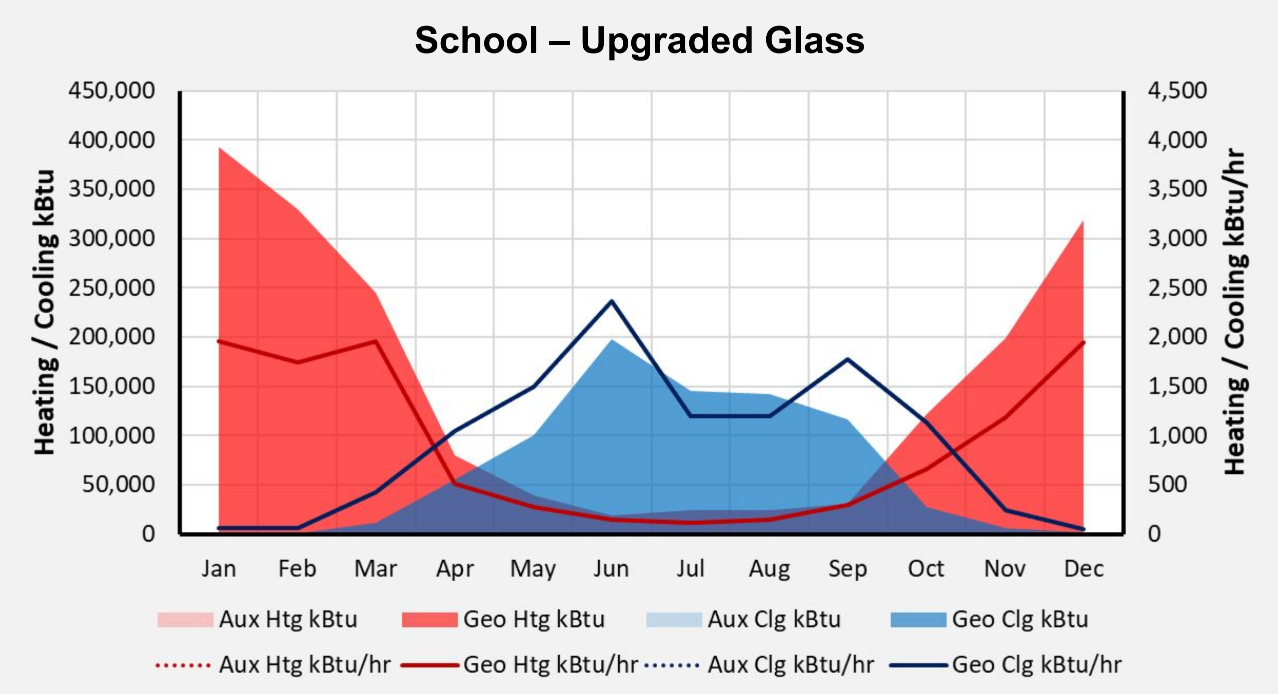
	School (Climate zone 5) - Constructed to ASHRAE 90.1			
	Clg kBtu	Clg kBtu/hr	Htg kBtu	Htg kBtu/hr
Jan	1081	56	418861	2017
Feb	1271	57	349758	1805
Mar	12164	461	259317	2035
Apr	58739	1094	85469	536
May	106315	1529	41575	296
Jun	207971	2429	19326	161
Jul	162502	1265	23788	118
Aug	158662	1259	23894	156
Sep	125248	1850	32144	307
Oct	29166	1192	130194	695
Nov	6952	268	211411	1237
Dec	1713	54	338655	2014
	871,784	**2,429**	**1,934,391**	**2,035**
	Tons	202	Tons	170
	Annual Cooling / Heating Ratio:			**0.45**



Changing glass specifications

- Lowering solar heat gain coefficient (SHGC) reduces cooling loads
- Lowering U-value (increasing R-value) reduces heating loads
- Small reduction in size of GHX

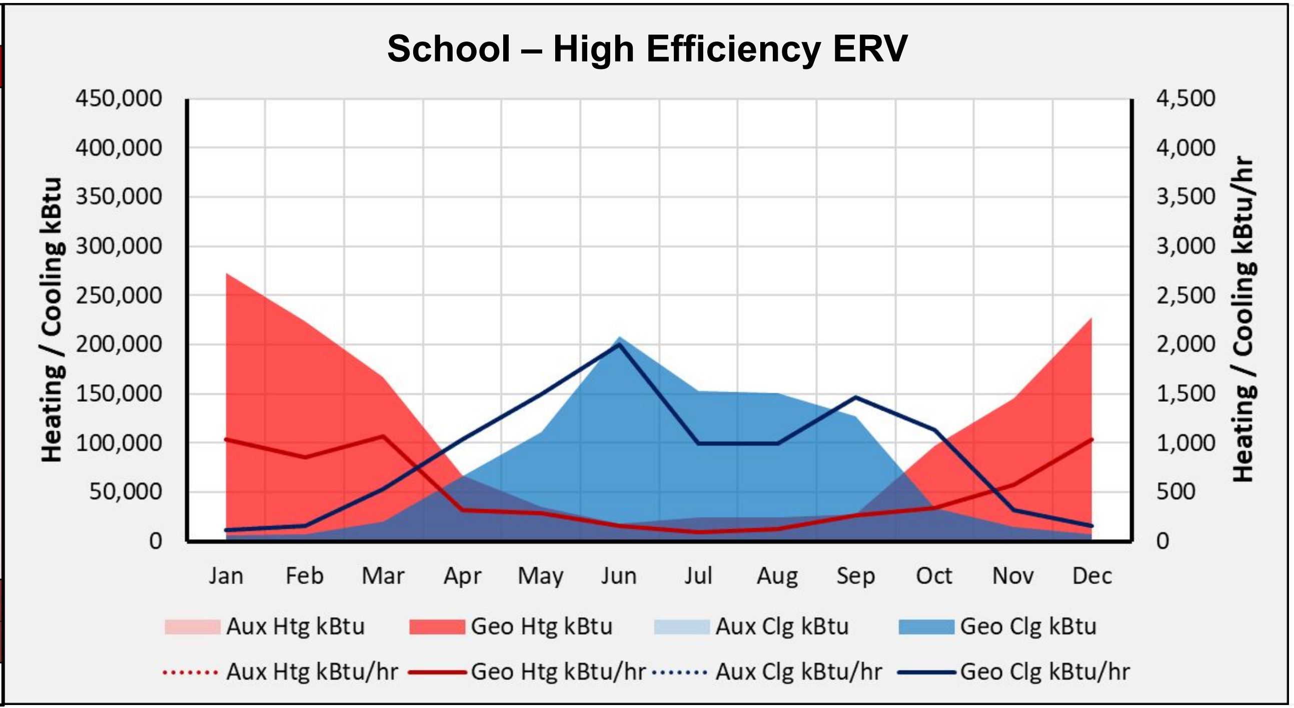
	School (Climate zone 5) - Upgrade Glass			
	Clg kBtu	Clg kBtu/hr	Htg kBtu	Htg kBtu/hr
Jan	1089	56	393350	1953
Feb	1147	57	330134	1744
Mar	11197	422	245140	1962
Apr	55168	1049	80108	511
May	100835	1494	39595	275
Jun	197380	2367	19124	147
Jul	144941	1201	23872	117
Aug	141733	1192	23960	151
Sep	116800	1771	30853	293
Oct	27482	1131	122122	660
Nov	6293	240	198858	1187
Dec	1756	54	319458	1950
	805,822	2,367	1,826,573	1,962
	Tons	197	Tons	164
	Annual Cooling / Heating Ratio:			0.44



Exhaust air energy recovery

- Reduces heating more than cooling loads in a cold climate
- Improves energy balance

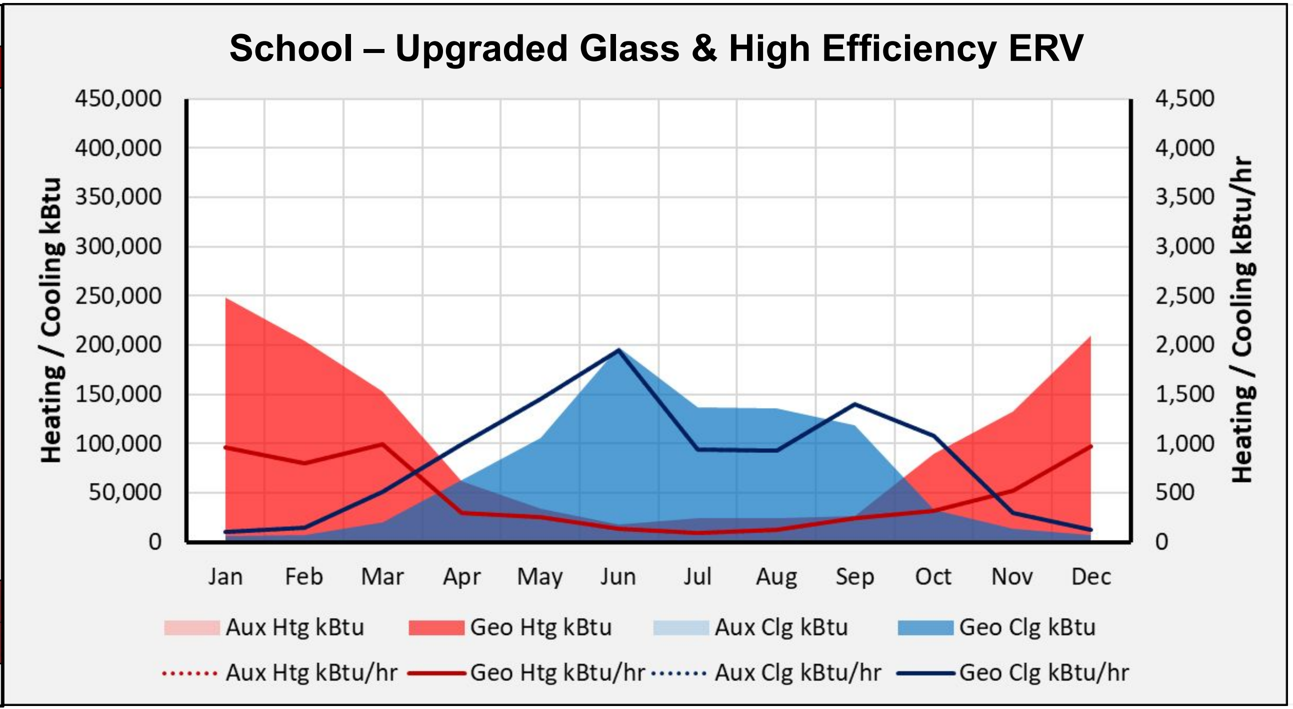
	School (Climate zone 5) - Add ERV			
	Clg kBtu	Clg kBtu/hr	Htg kBtu	Htg kBtu/hr
Jan	5857	110	273180	1039
Feb	7216	158	223763	854
Mar	20516	534	166807	1064
Apr	66477	1035	66809	317
May	111204	1498	35320	281
Jun	208393	2003	18046	157
Jul	153110	997	23844	98
Aug	151078	997	23910	125
Sep	126979	1460	28011	268
Oct	34384	1135	97213	342
Nov	14245	318	145499	576
Dec	7351	159	227933	1038
	906,809	**2,003**	**1,330,332**	**1,064**
	Tons	167	Tons	89
	Annual Cooling / Heating Ratio:			**0.68**



Combining energy efficiency measures

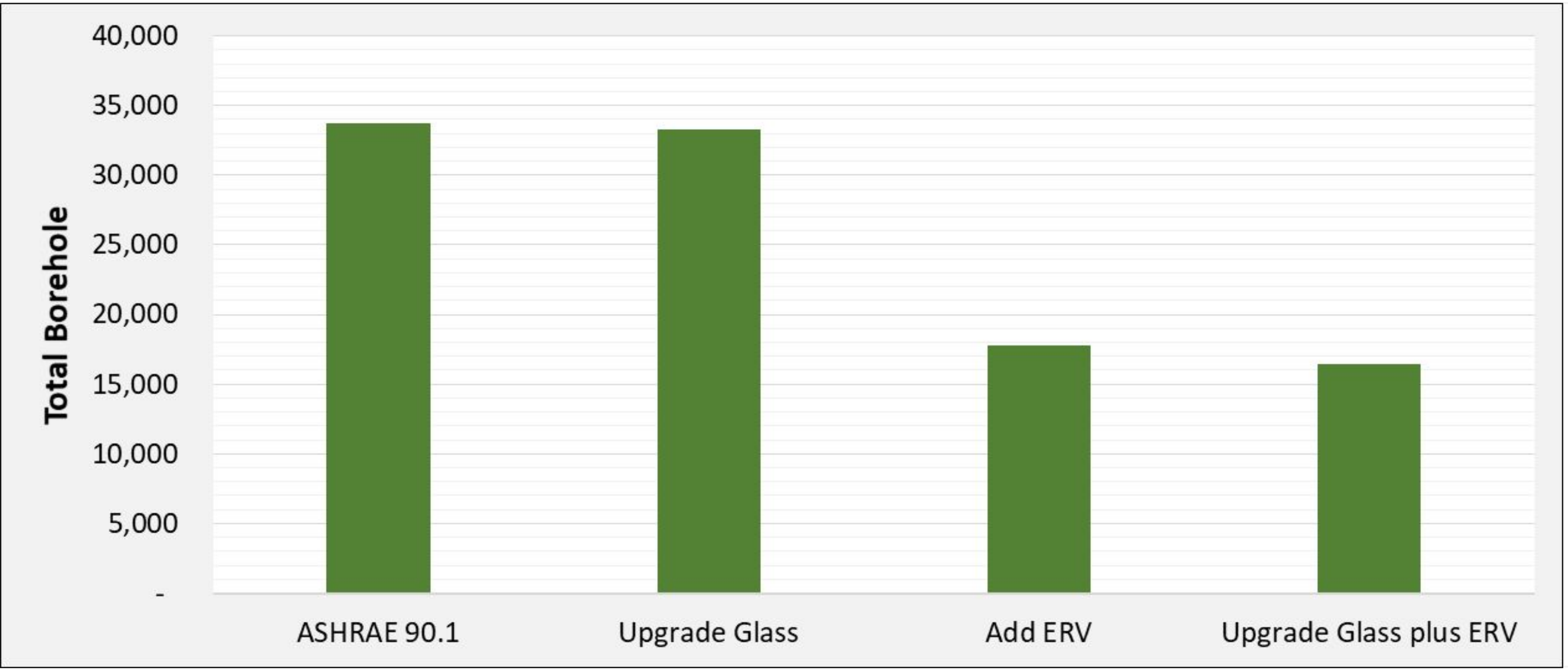
- Upgraded glass and ERV further reduces cooling loads, with slightly better energy balance to GHX

	School (Climate zone 5) - Upgrade Glass plus ERV			
	Clg kBtu	Clg kBtu/hr	Htg kBtu	Htg kBtu/hr
Jan	6127	108	248563	961
Feb	6966	145	204318	797
Mar	19638	506	153002	993
Apr	62873	989	61901	292
May	105658	1451	33560	258
Jun	197889	1948	17829	141
Jul	137177	940	23893	96
Aug	135481	930	23939	125
Sep	118832	1402	26609	242
Oct	32472	1078	89671	317
Nov	13102	291	132758	526
Dec	7202	128	209269	971
	843,417	**1,948**	**1,225,312**	**993**
	Tons	162	Tons	83
	Annual Cooling / Heating Ratio:			**0.69**



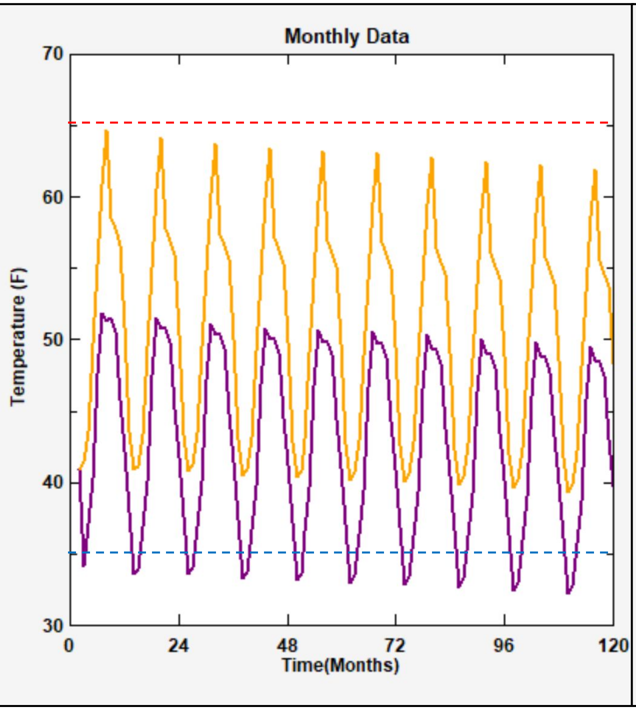
Changes to building affect GHX size and cost

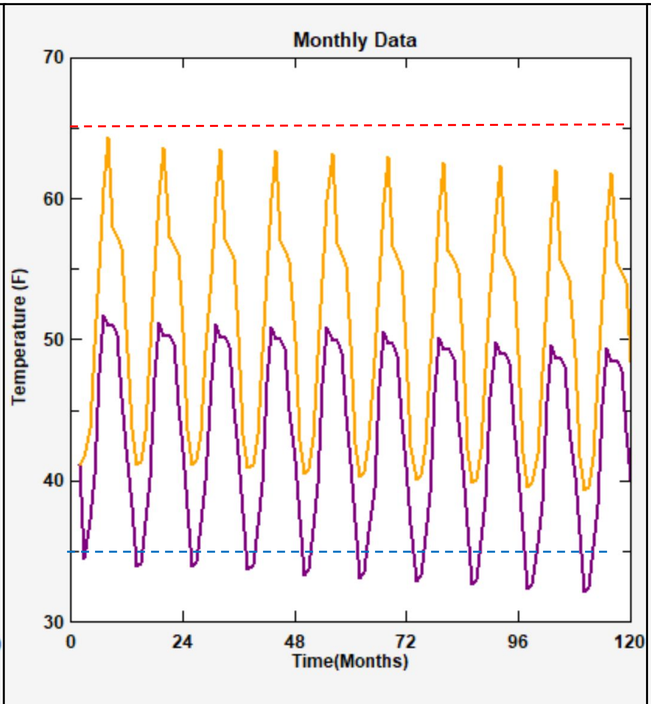
- Adding efficiency measures to a building changes peak and annual energy loads and changes the size / cost of GHX required
- Addition of ERV balances energy loads, reduces borehole required by approximately 45-50%

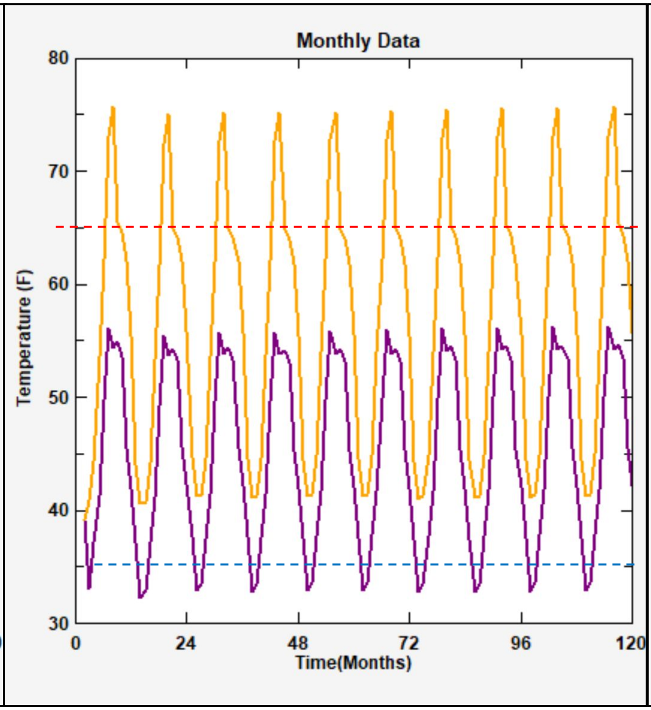


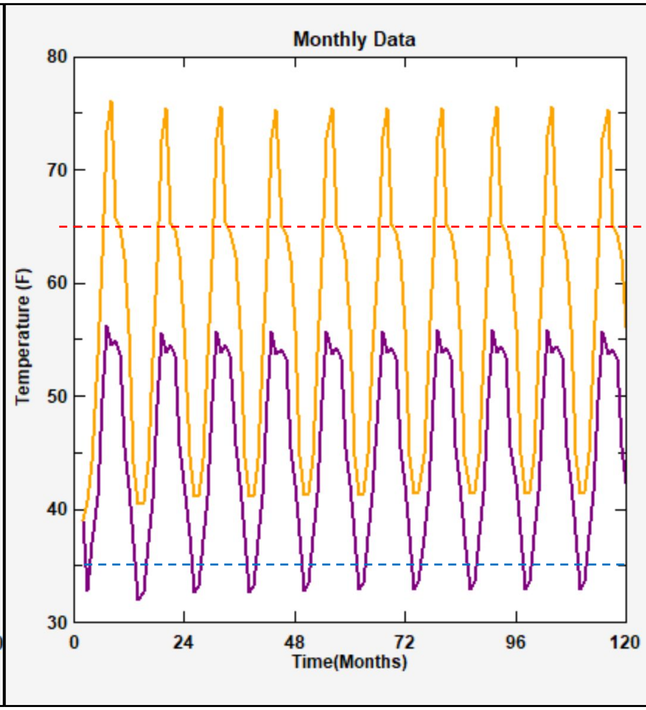
Changes to building affect long-term GHX performance

- Building loads are heating dominant without ERV. GHX temperatures drop by approximately 3-4°F over 10 years
- ERV helps balance annual energy loads, reduce potential of degrading over time

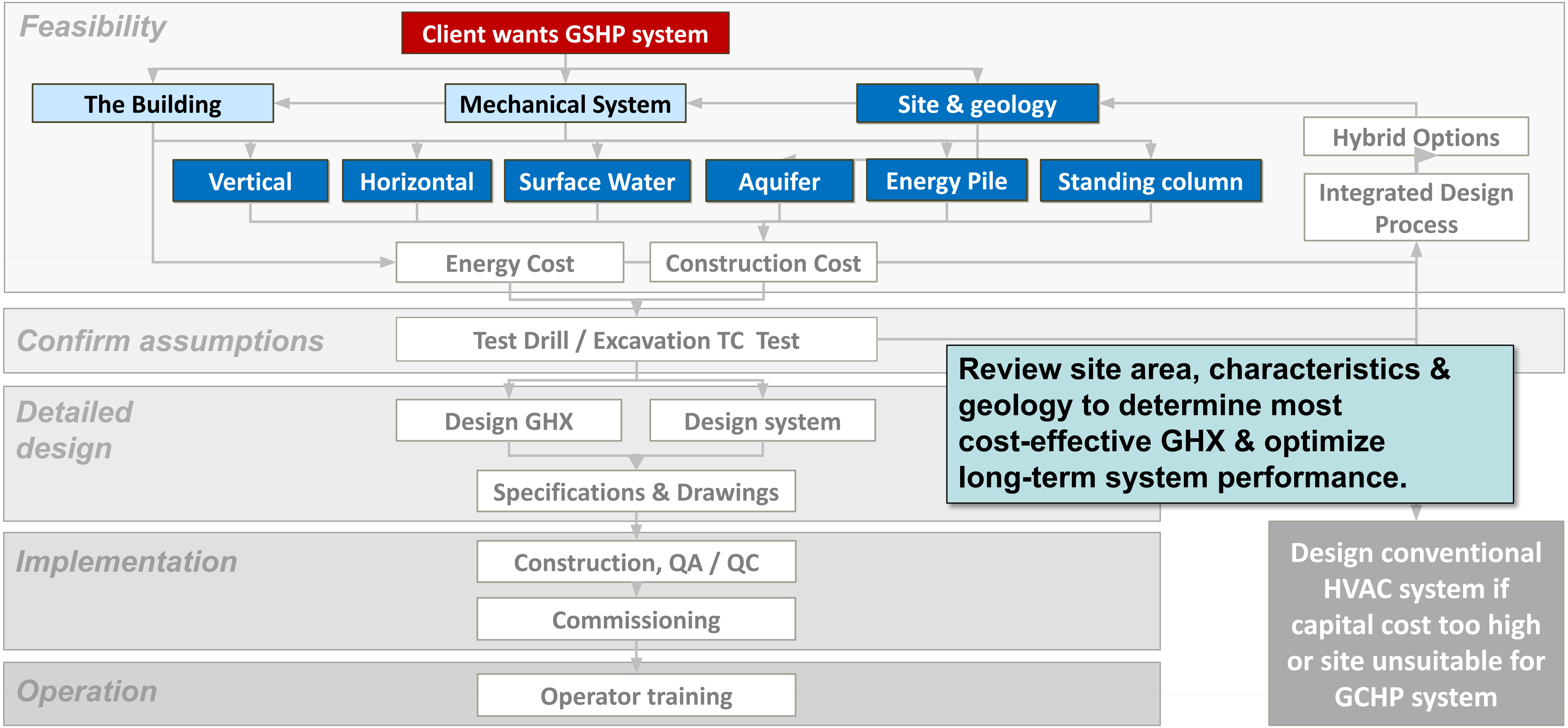








GHX type and configuration and contractor capabilities




Geology determines how much
energy the ground can provide

Thermal properties of soil and rock affect size and installation cost

- Thermal properties of rock / soil GHX is built determines speed & amount of heat transferred to and from the earth
- Different soils & rock require different drilling techniques…affect drilling costs
- Review of water well databases, interviews with drilling contractors, geologists can provide preliminary modeling information

Site constraints determine how GHX configuration

Vertical GHX options

- Geological conditions and site constraints can challenge contractors
- Angle drilling, drilling with limited drilling technology, drilling under and inside buildings, or using the building's structure as the energy resource are options that can be considered depending specific project constraints

Alternatives to vertical GHX

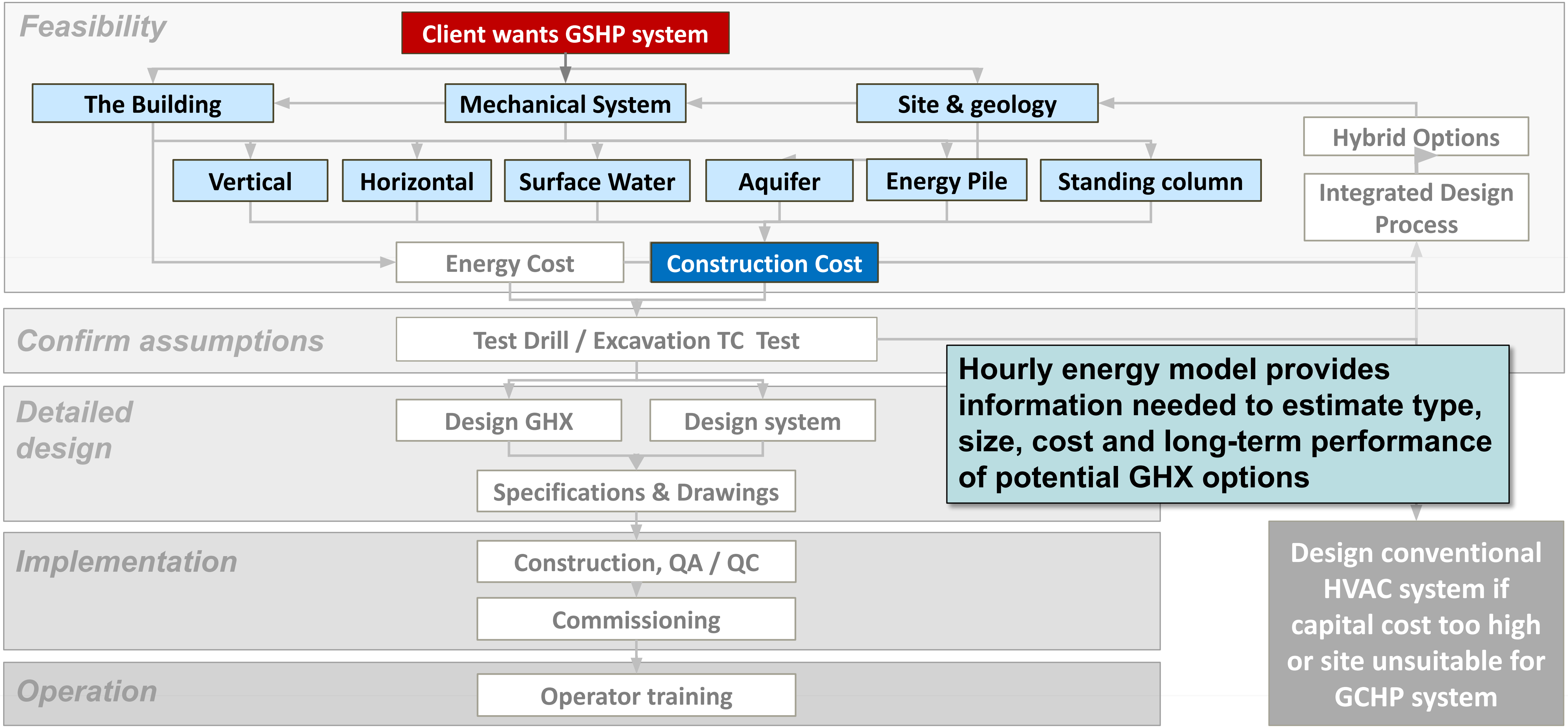
- Depending on the site and geology, alternatives to vertical boreholes can be considered
- Horizontal excavation or drilling
- Surface water heat exchangers



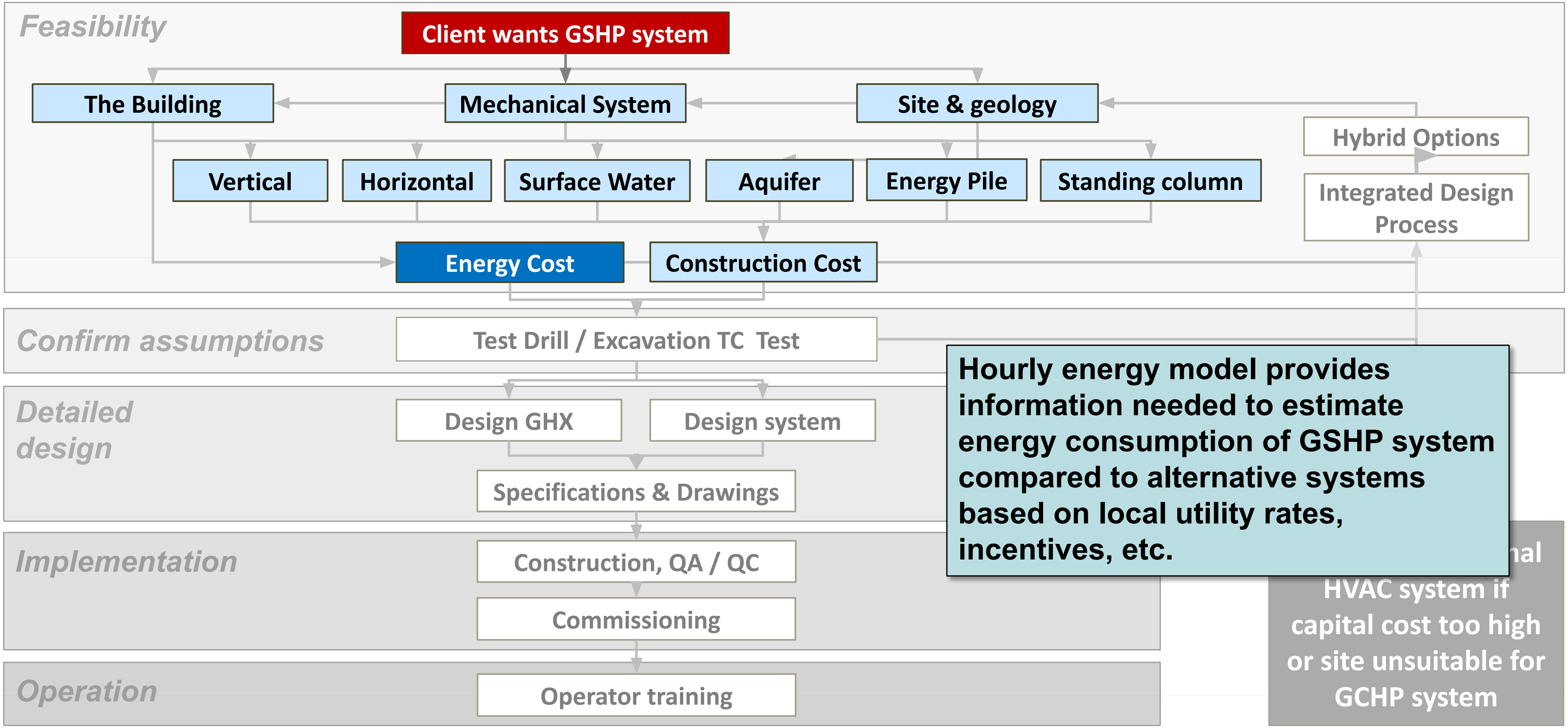



Contractor capabilities determines cost-effectiveness

Contractor capabilities, geology, site constraints



Energy modeling and utility rates



Hourly energy model provides information needed to estimate energy consumption of GSHP system compared to alternative systems based on local utility rates, incentives, etc.

Return on investment

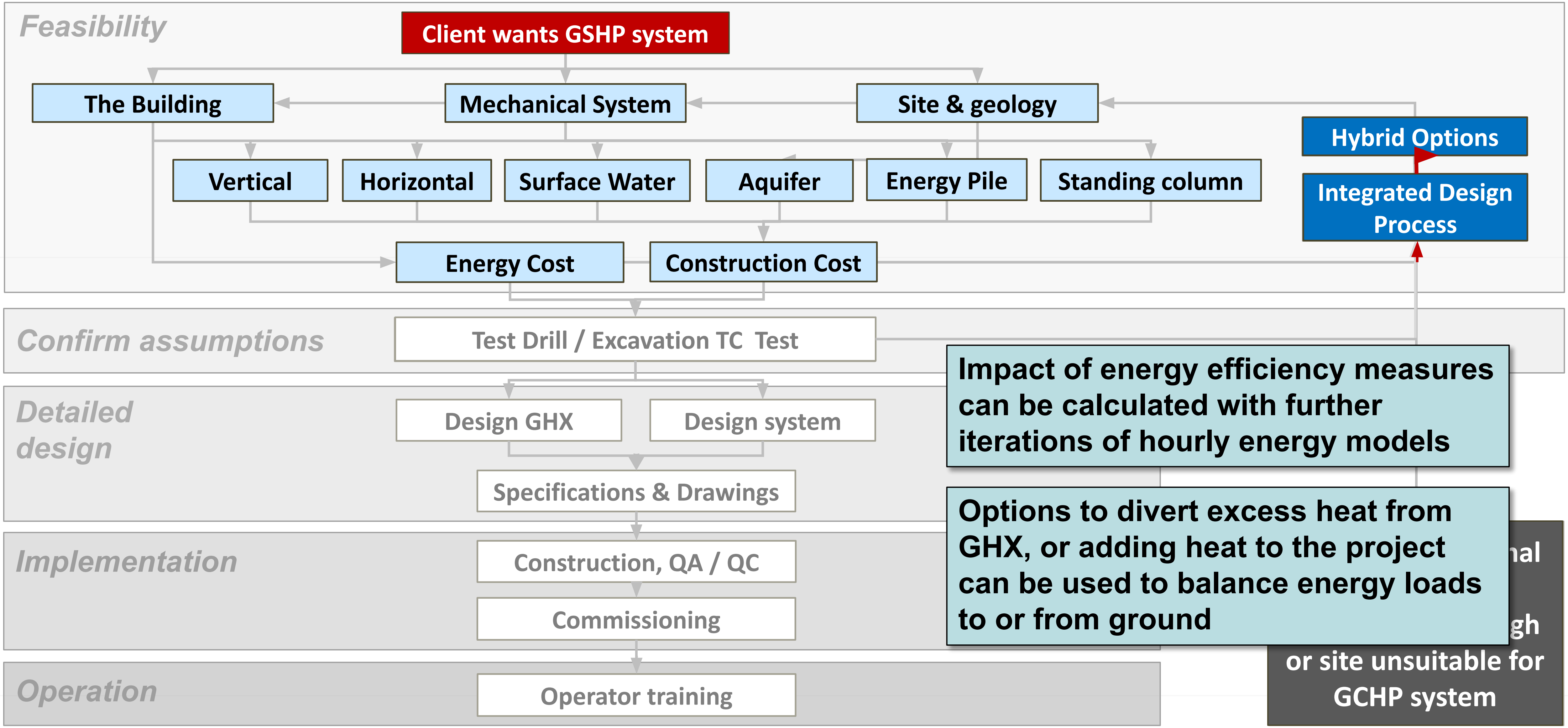
Description	Standard ASHRAE 90.1 Building	Optimized Building with Gas Heating	Optimized Building with GSHP
Base System Cost[1]	$5,250,000	$5,250,000	$5,250,000
GHX System Cost[2]	---	---	$652,800
Exhaust Energy Recovery Cost[3]	---	$350,000	$350,000
Upgraded Glass Cost[4]	---	$87,500	$87,500
Total Cost	**$5,250,000**	**$5,687,500**	**$6,340,300**
Government/Utility Incentives	---	---	($325,000)
Modified Total Cost	---	---	**$6,015,300**
INCREMENTAL COST	---	**$437,500**	**$765,300**

Heating and Cooling Costs			
Total Heating Cost[5]	$47,246	$22,098	$6,439
Total Cooling Cost[6]	$3,804	$3,060	$1,553
Total Heating and Cooling Cost	$51,050	$25,158	$7,992
ANNUAL COST SAVINGS	---	**$25,892**	**$43,058**

Financial Analysis[7]			
Return on Investment [20 years]	---	**7.2%**	**6.8%**
Net Present Value [20 years]	---	**$36,004**	**$37,038**
Internal Rate of Return [20 years]	---	**3.3%**	**3.0%**
Simple Payback	---	**16.9 years**	**17.8 years**

- Building owners base their decision to install a GSHP system on money
- Minimizing cost of installing the GHX while maximizing system efficiency increases return on investment
- Hourly energy loads translated into energy consumption, cost with local utility rates and CO_2 emissions
- Cost of recommended energy efficiency measures to balance loads are included

Owner’s decision to move forward with GSHP or conventional HVAC



Architectural and mechanical design iterations

- Additional energy models to balance energy loads…options might include electrochromic glass, daylighting and occupancy controls, green roof, low temperature perimeter radiant heating in place of high temperature convectors

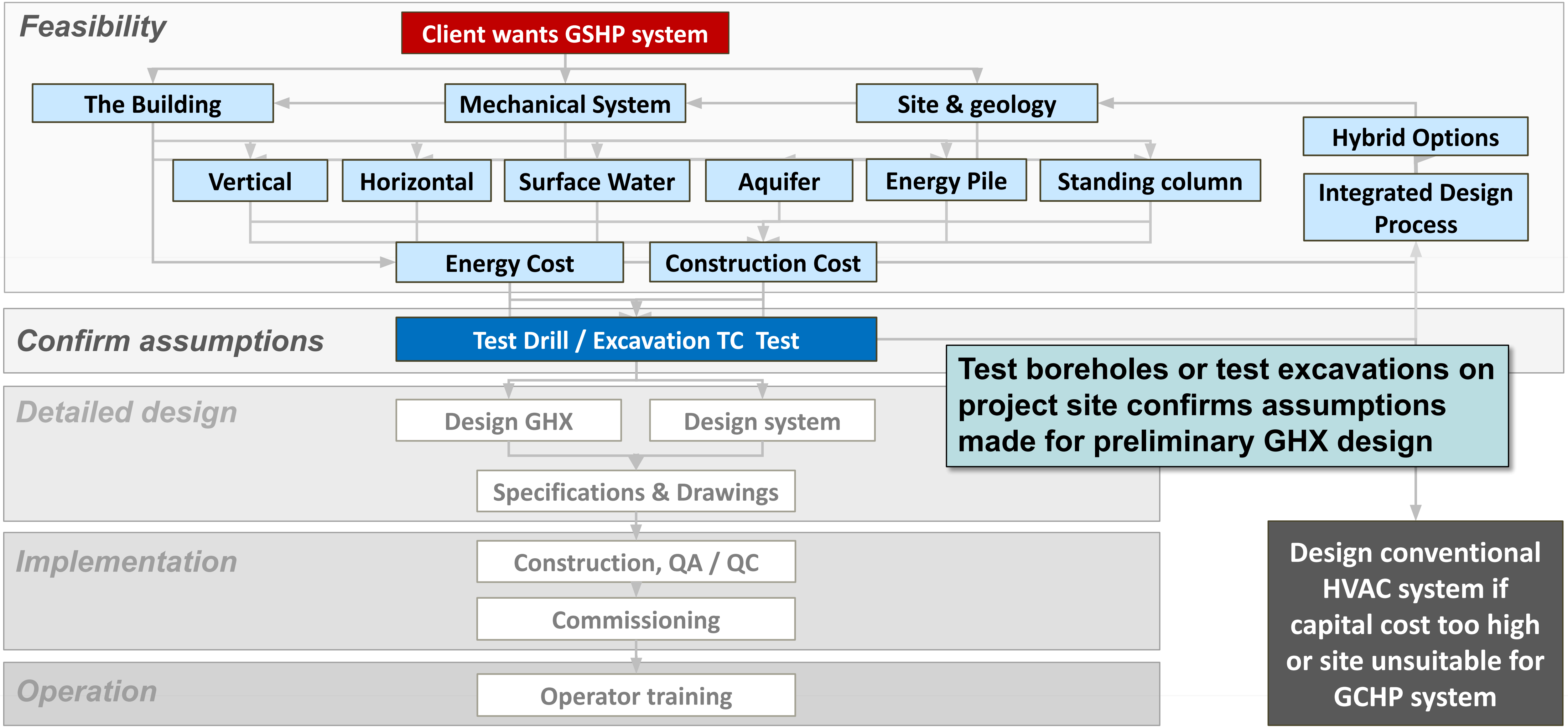
Auxiliary heating / cooling devices

- Snow melt or other beneficial to dissipate excess heat
- Renewable heat source to recharge heating dominant GHX
- Fluid coolers or boilers to dissipate or provide additional heat as needed
- Water well to supply or dissipate excess heat





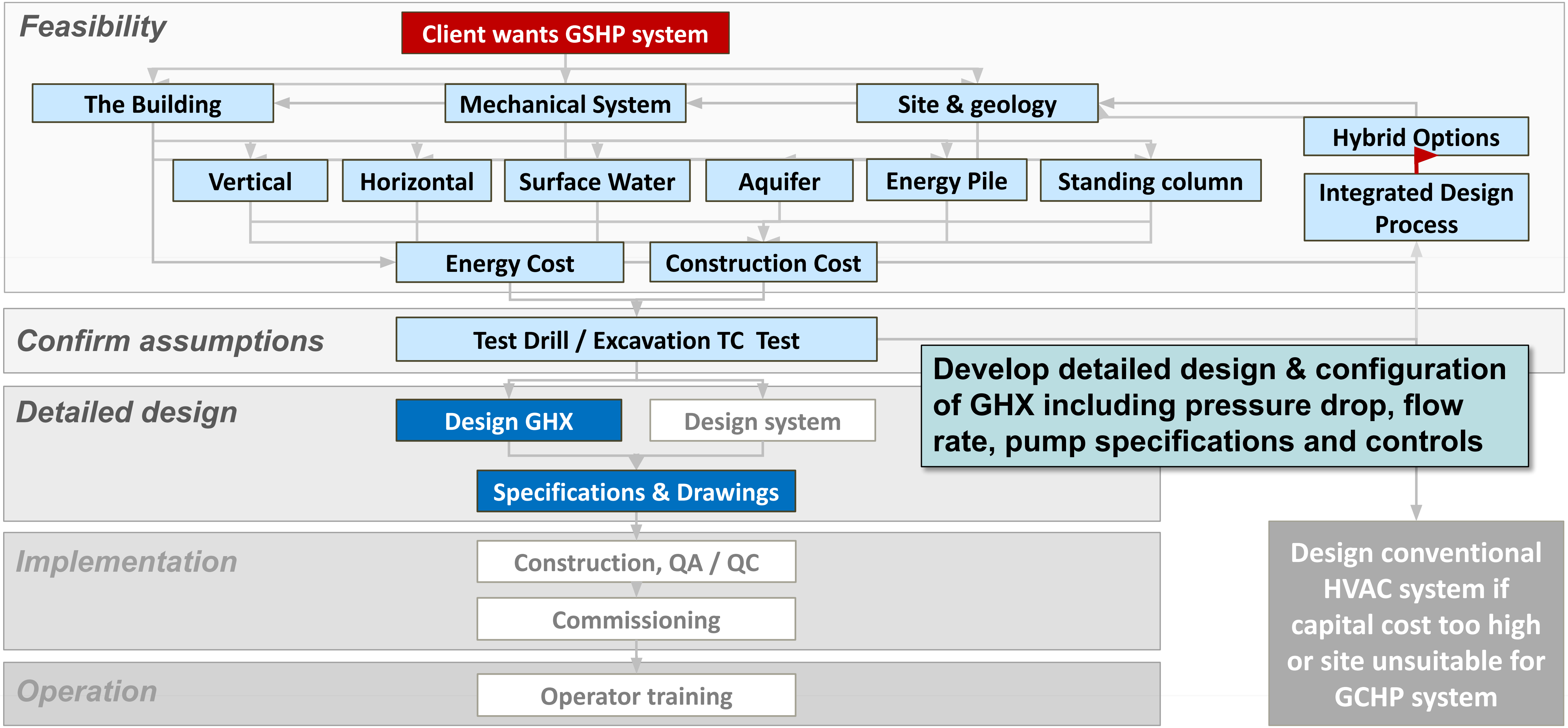
Confirming preliminary geological assumptions before final design



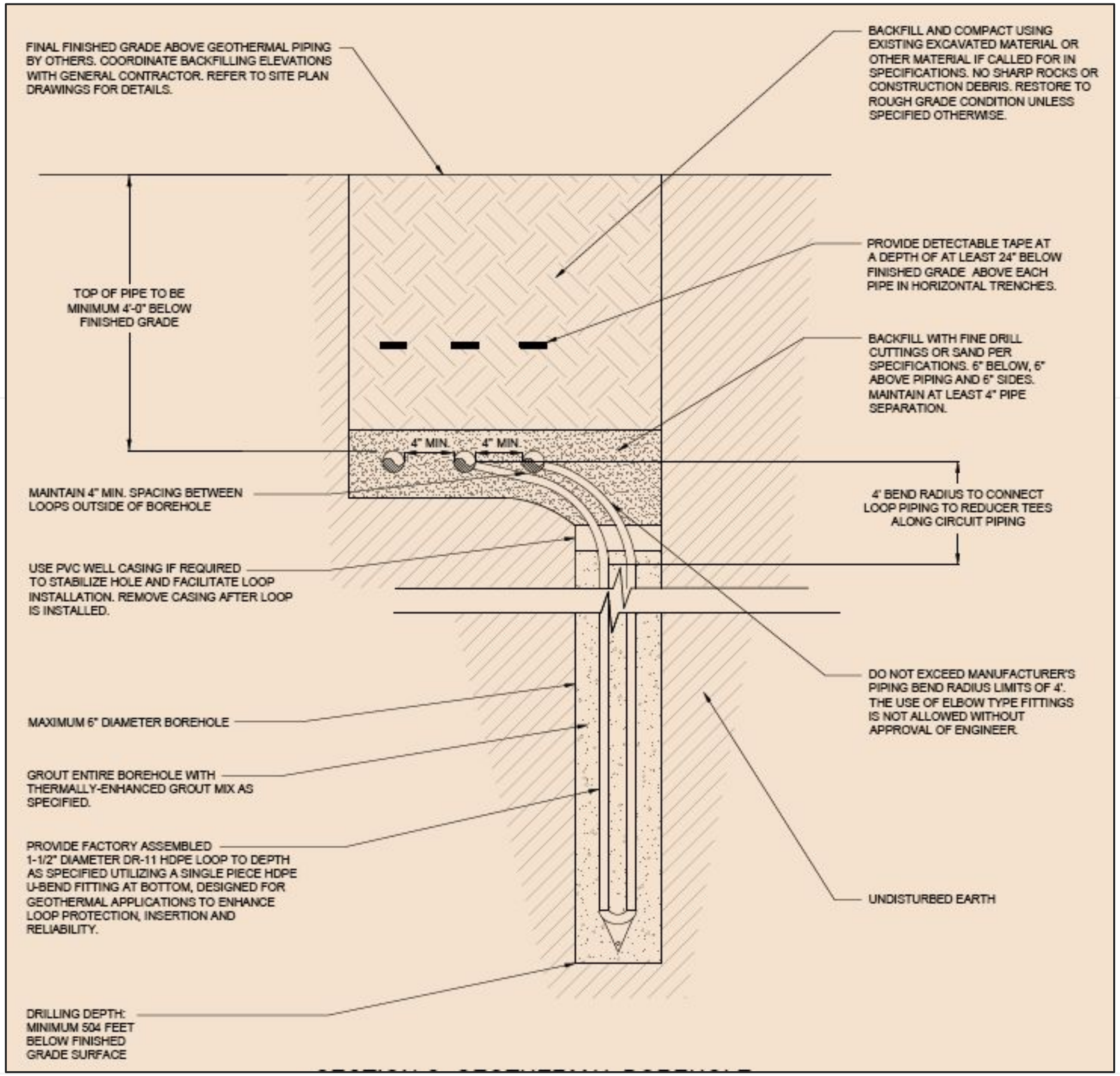
Confirming soil properties before final GHX design

- Cost of thermal conductivity test includes cost of borehole ($3-12,000) plus cost of actual test ($4-8,000). Total: $7-20,000
- Preliminary GHX modeling can often be completed based on information from water well databases, interviews with drillers, geologists.
- Preliminary modeling establishes test borehole depth, U-tube size, location to integrate into final design

Detailed GHX design

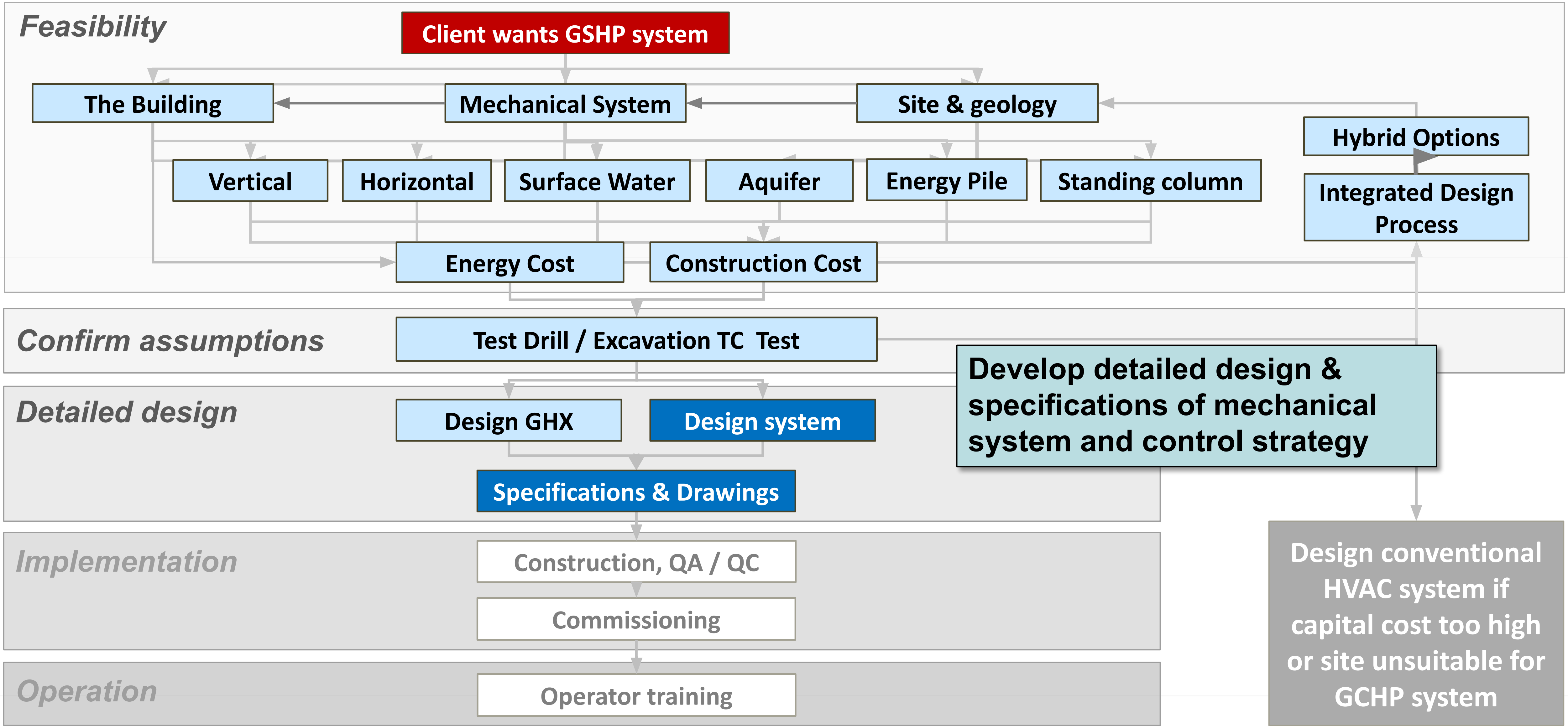


GHX design details



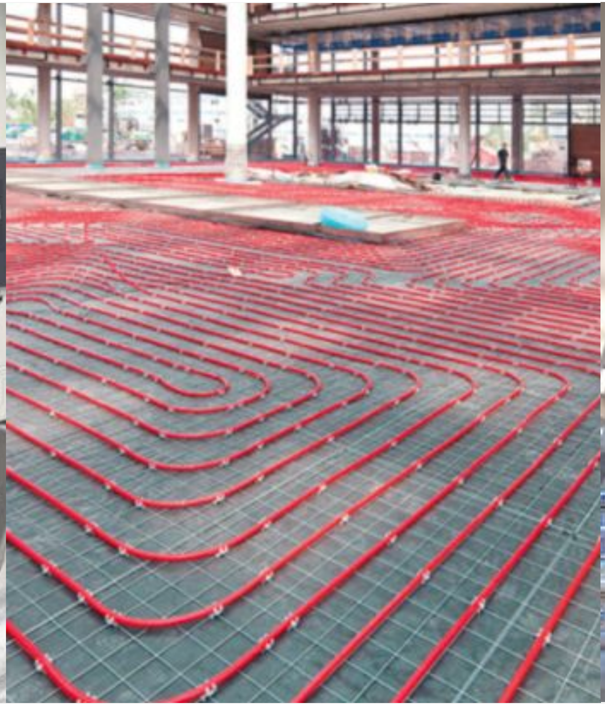
- Design details must be laid out in detail
- GHX is critical component of GSHP system…buried / difficult to repair. Design should be reviewed to ensure:
  - Correct soil properties used
  - Appropriate construction methodology
  - System can be flushed effectively
  - Appropriate heat transfer fluid specified
  - Commissioning agent understands flushing procedures

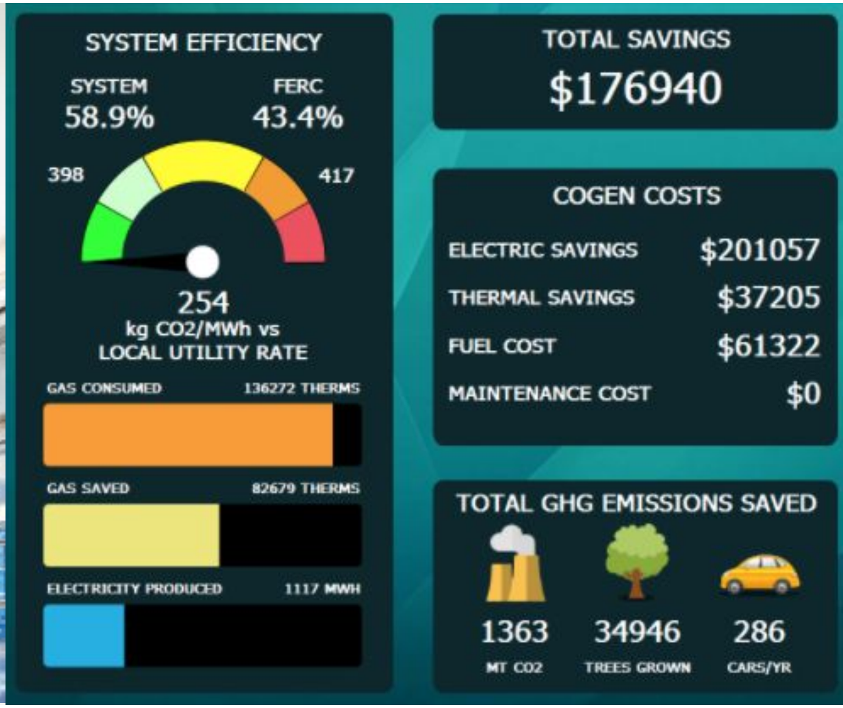
Optimizing mechanical system design to work with GHX



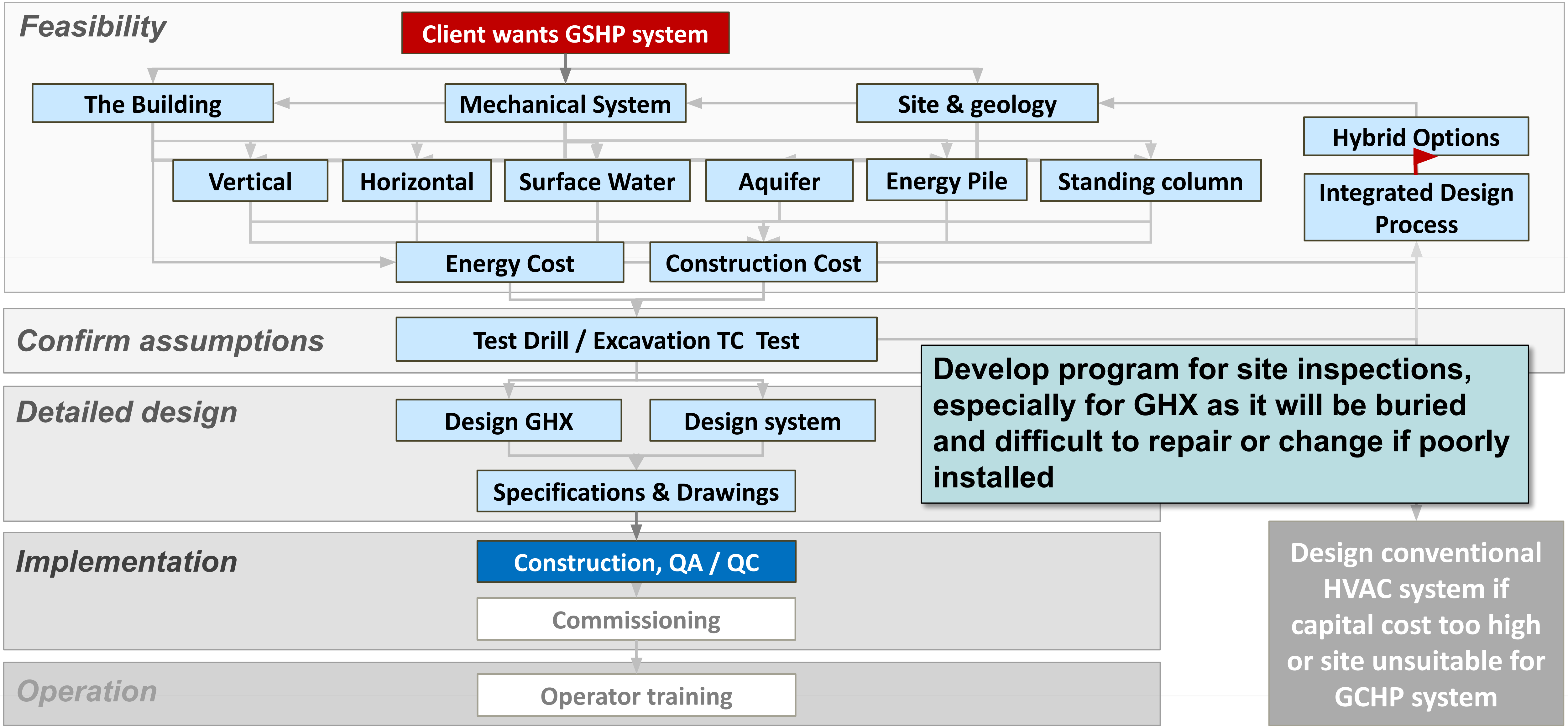
Optimizing mechanical system to perform well with GHX

- Pumping energy, distribution system temperatures and ongoing system monitoring are critical in ensuring a GSHP system is optimized to work well with heat pump equipment and a GHX





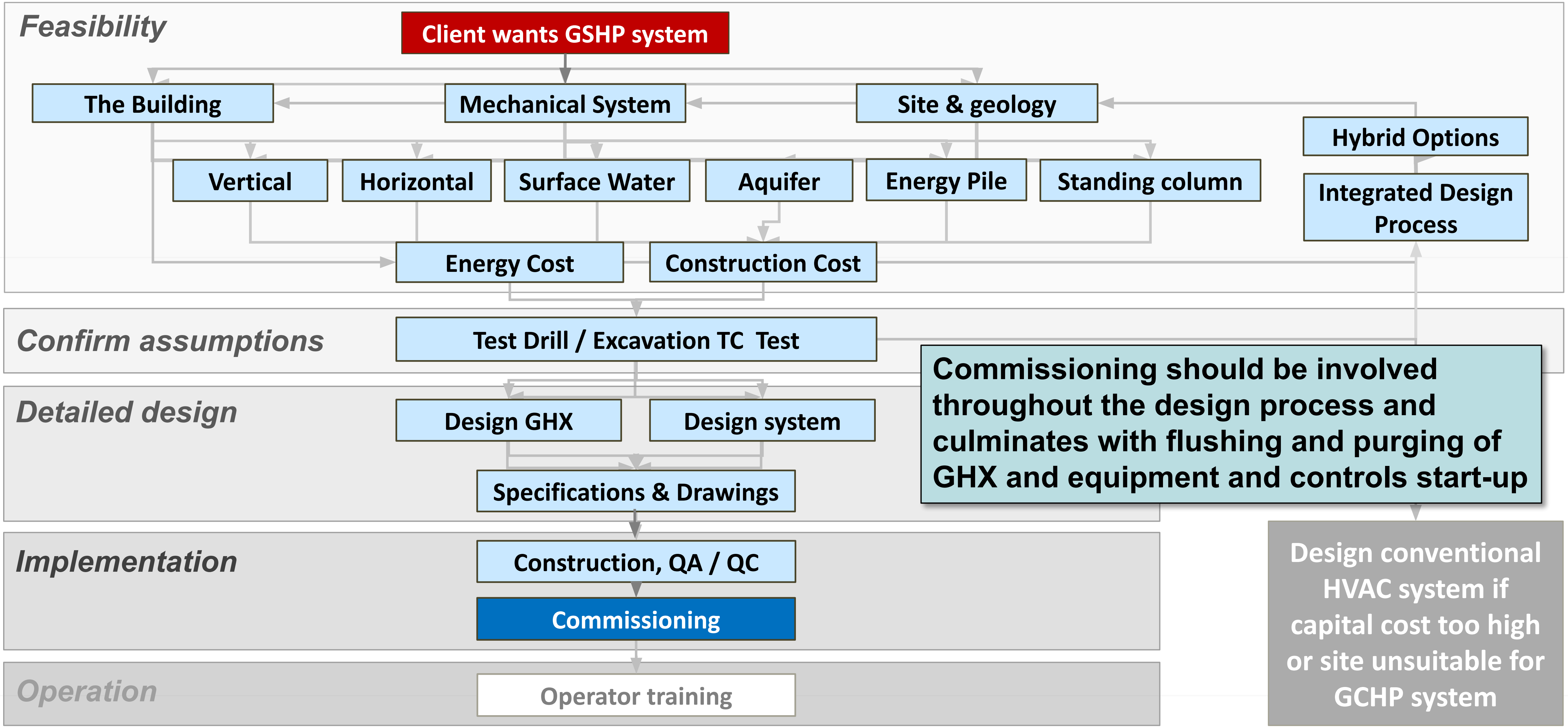
Ensuring system is installed as designed



Quality installation

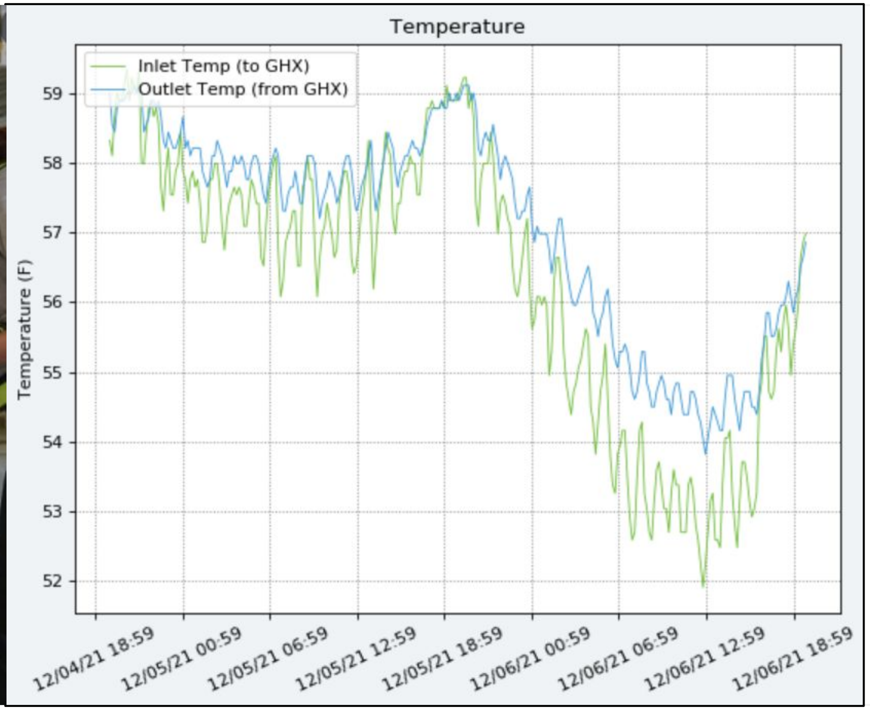
- GHX is buried and difficult if not impossible to repair if needed. A detailed quality assurance / quality control program is needed to ensure correct installation.

Ensuring is installed as specified

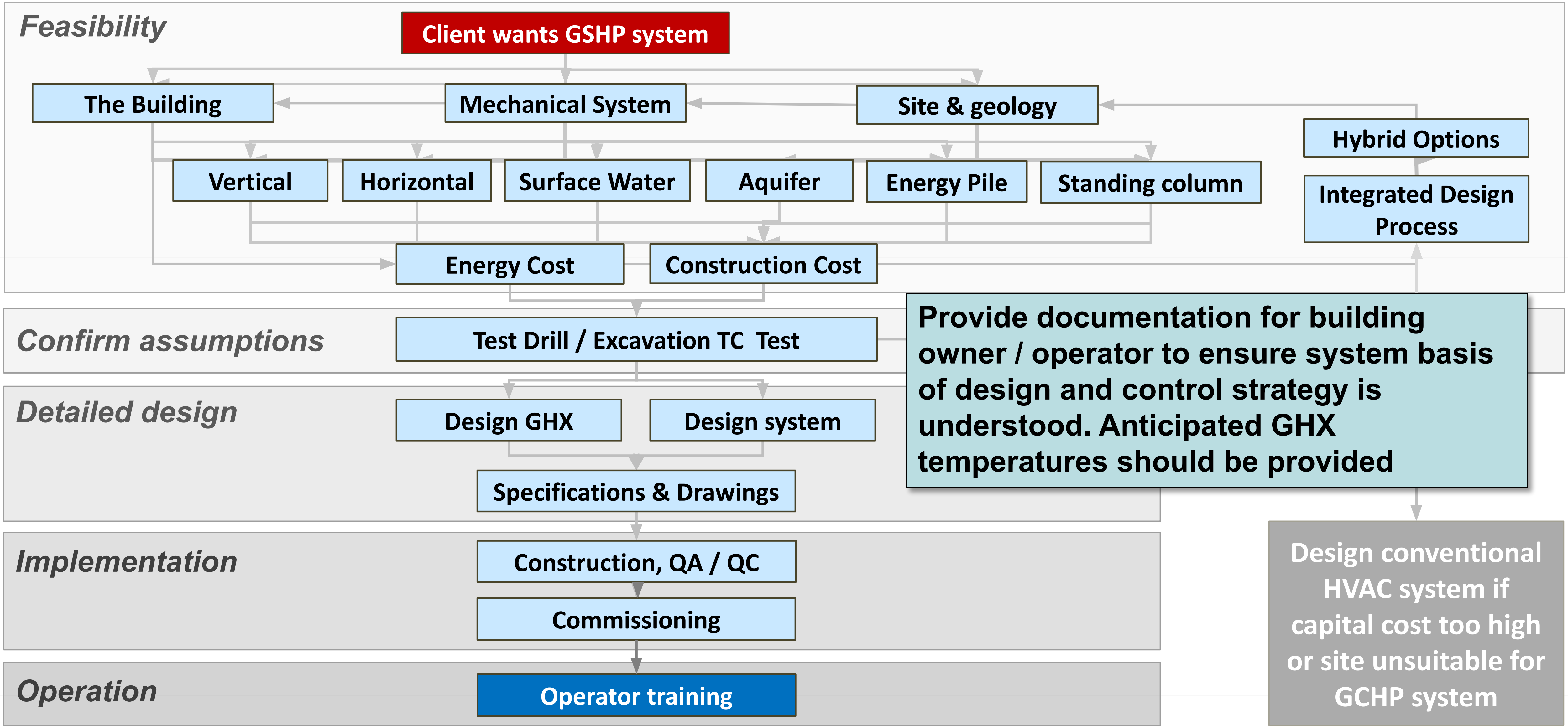


Commissioning and ongoing commissioning

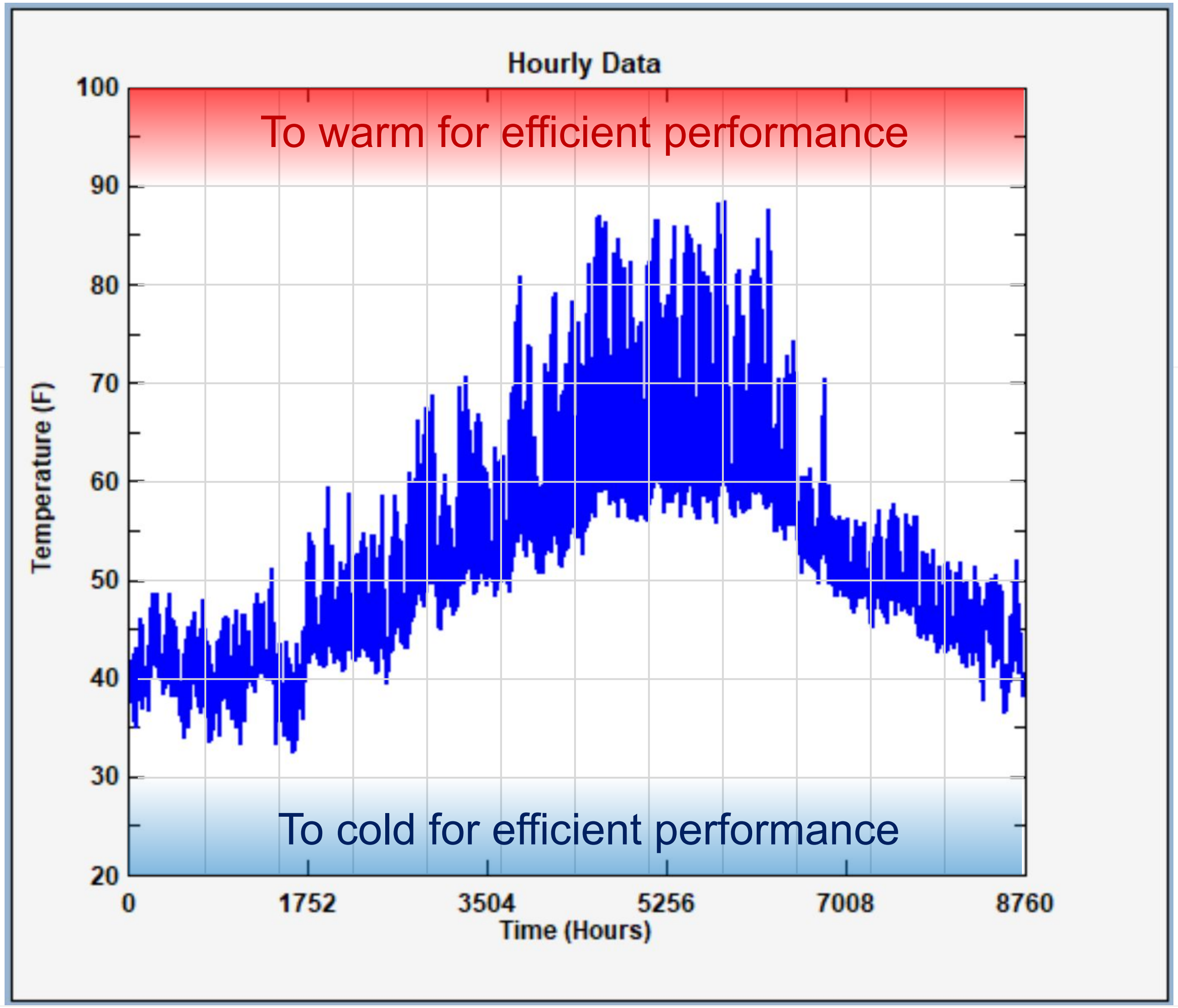
- Ensuring the system is installed and operating as designed as well ongoing monitoring moving forward is important to efficient system operation



Information for building operators

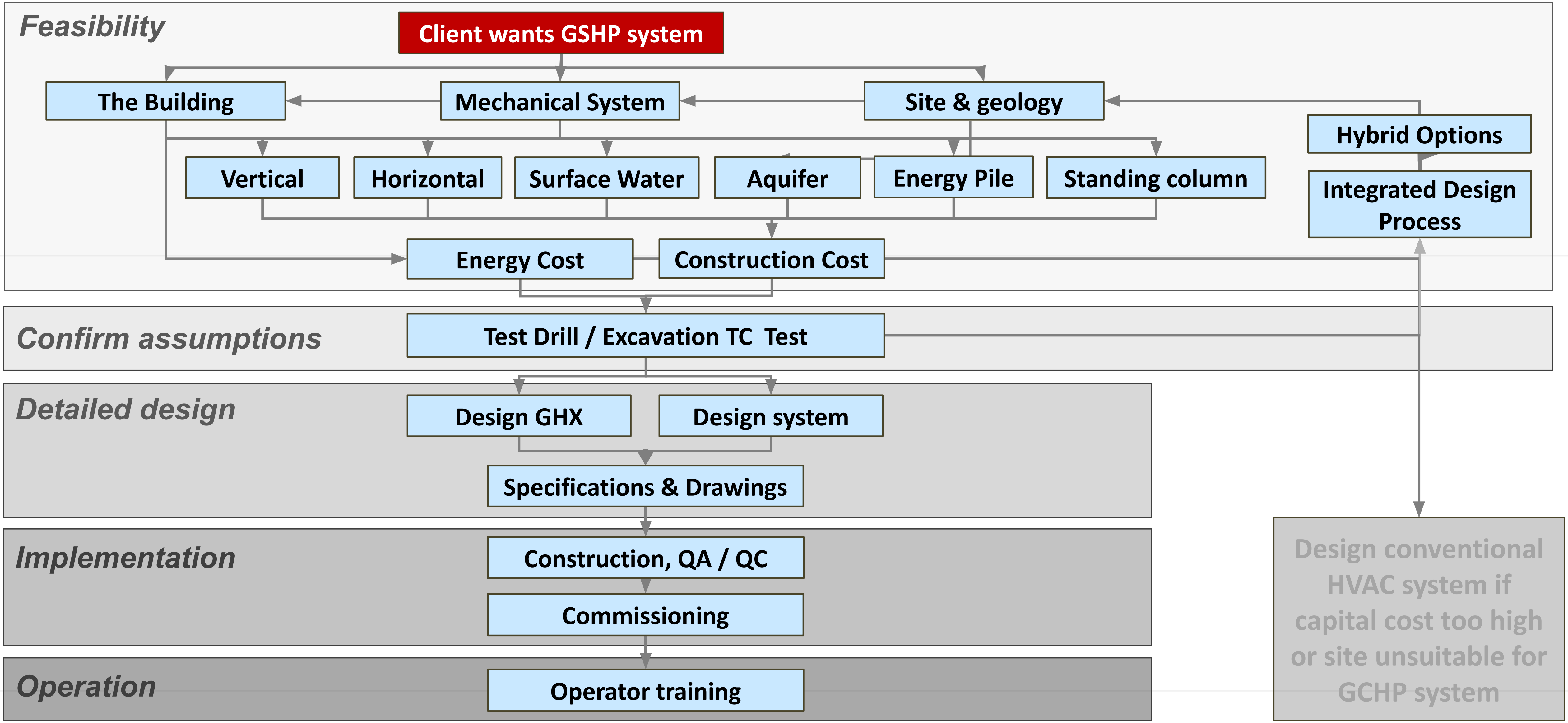


What a building owner / operator needs to know



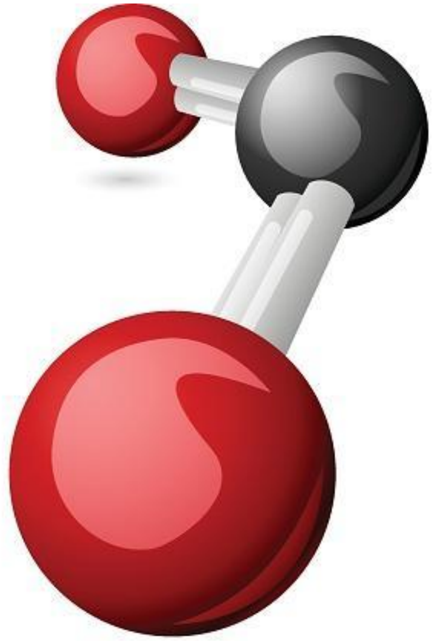
- Most geothermal heat pumps are designed to operate efficiently with entering water temperatures between 30° and 90°F
- Operators need to be aware the temperature should be monitored and what they can do if it starts operating outside of efficient operating parameters

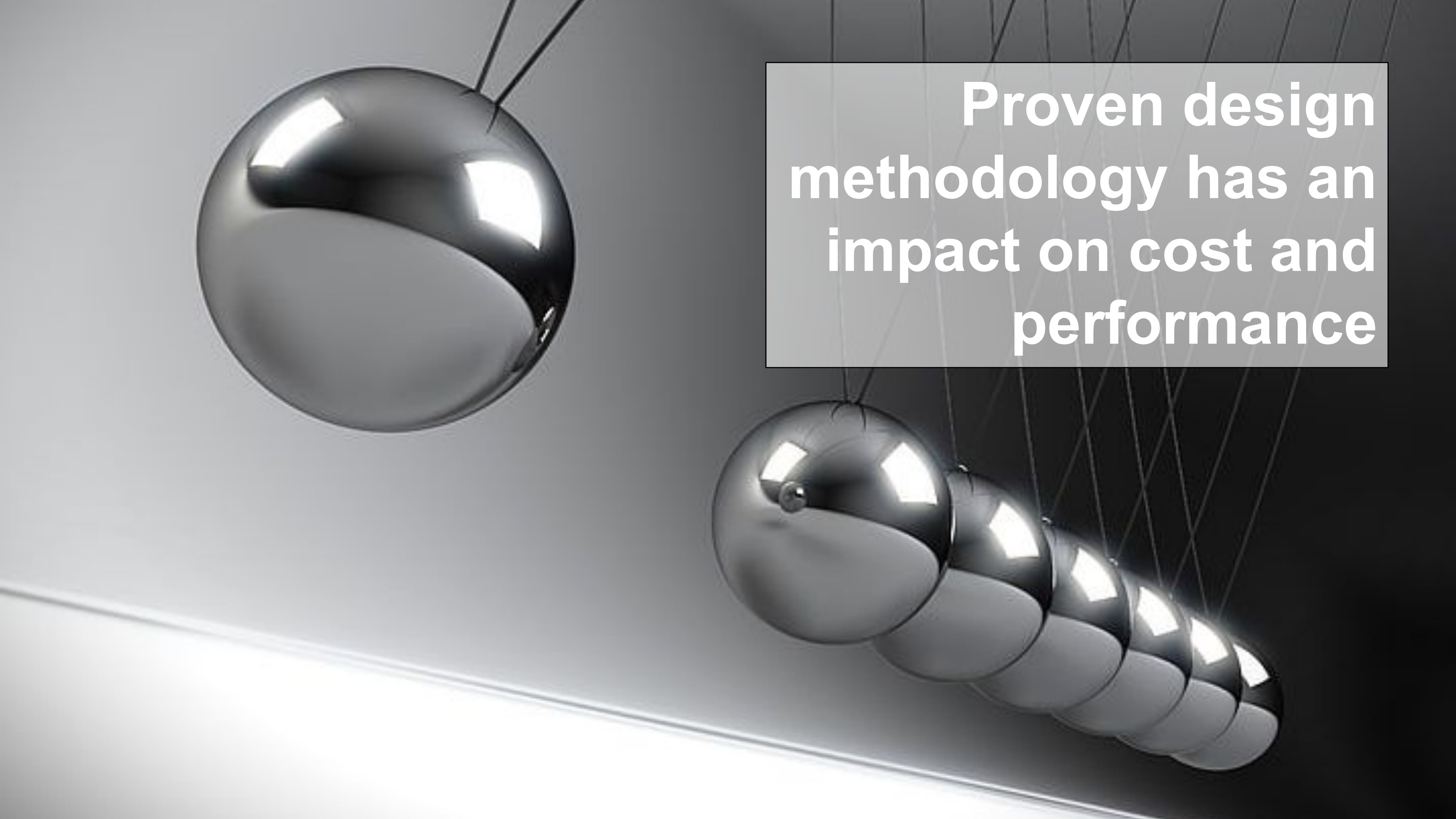
Design methodology overview



Well designed GSHP system reduces cost, mitigates risk

- Offers a solid return on investment
- Ensures reliable, high-performance system
- Reduces energy consumption and CO_2 emissions
- Can work virtually anywhere in the world





Proven design methodology has an impact on cost and performance

Two types of GSHP rebates from Efficiency Manitoba:

1. For Existing Buildings

Efficiency Manitoba's **Ground Source Heat Pump** (GSHP) program is for existing residential and commercial buildings that currently have a Manitoba Hydro electric service and are heated using electricity or natural gas.

- The GSHP installer must be a member in good standing with the MGEA (Manitoba Geothermal Energy Alliance)
- Heat loss calculations and loop design are required
- The rebate is calculated as the lesser of:
  - $2.50/square foot of heated space
  - $120/MBH of installed heating capacity
  - $120/MBH of building's eligible base transmission and infiltration heating load

- Approval must be obtained from EM prior starting any work on your project

- **More detail on the program can be found at efficiencyMB.ca/heatpump**

2. For New Buildings

Efficiency Manitoba's **New Buildings Program** offers technical guidance and financial incentives for new construction projects classified as Part 3 buildings that are required to follow the Manitoba Energy Code for Buildings 2013.

- The New Buildings Program includes two paths; the **Energy Modelling Assistance Incentive** and the **Performance Path**.

Two types of GSHP rebates from Efficiency Manitoba:

2. For New Buildings - Continued

- The **Energy Modelling Assistance Incentive (EMAI)** is designed to encourage project teams to use energy modelling as a tool in the design process to help evaluate design decisions. The deliverable is set up in such a way that makes the energy model results easy to understand for owners and the rest of the project team.
  - The incentive is up to $10,000 and is based on the cost of modelling for the project.
    - The first up to $5,000 is paid after we receive and verify the EMAI deliverables
    - The remaining up to $5,000 is added to the performance path incentive upon successful completion of the performance path.

  To be eligible for this path an application and design energy model report, must be submitted to EM before the project's tender date and before the project is issued building permit.

- The **Performance Path** looks at your building's performance over the Manitoba Energy Code for Buildings (MECB) reference case in the final, as-built model and includes several commissioning deliverables.
  - Incentives are determined based on the building performance above code and range between $0.50/sq. ft. – $2/sq. ft.

  To be eligible for this path, you must submit the application no later than 6 months after a building permit is issued, however, the sooner the better to ensure all project team members are aware of the requirements for successful completions. Projects that achieve 10% better than the current MECB also receive an Energy Efficient Certification from Efficiency Manitoba.

- **More detail on the program can be found at efficiencyMB.ca/newbuildings**

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Introduction to Ground Source Heat Pump Systems

March 6, 2023

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