

Building Energy Modeling

The Foundation of a GHX Design

Jacky Kinson, EIT

CDM Smith

October 22, 2024

Learning Objectives

1.

2.

3.

- Understand the components of building energy modeling
- Understand the effect of building energy modeling on ground heat exchanger (GHX) design for an individual building
- Understanding the effect of building energy modeling on GHX design for a district geothermal system



Building Energy Modeling Components



Building Energy Modeling Tools



... and more!

Building Energy Modeling Components

- Weather Data (location, TMY3)
- Building Area (sf)
- Building Occupancy
- Space Temperature Setpoints
- Ventilation Loads (ASHRAE 62.1)
- Internal Loads (equipment, lighting, people)
- Building Envelope (ASHRAE 90.1, Passive House)
- Infiltration Loads
- Schedules (occupancy, lighting, equipment)

Building Energy Modeling Applications

Business-as-usual

Code Compliance/ ASHRAE 90.1

Exceeding Code Compliance

- Existing buildings
- Poor Insulation

- Insulation
- BMS Controls
- Energy Recovery

- Passive house design
- Heating dominant loads could become cooling dominant loads

Building Energy Modeling Accuracy

- GOAL: Capture the actual building energy performance
- Temperature setpoints (design vs. actual)
- Calibrate with utility bills (natural gas, electricity)
- Schedules
 - Occupancy/Lighting/Equipment
 - Domestic Hot Water Hourly Load Profiles



Domestic Hot Water Hourly Load Profiles





Figure 15. Residential Hourly Hot-Water Use, 95% Confidence Level



Figure 16. Residential Average Hourly Hot-Water Use Patterns for Low and High Users

HOUR

9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

2

1 2 3 4 5 6

8

7

rns for Low and High Users Figure 17. Residential Hourly Hot-Water Use Pattern for Selected High Morning and High Evening Users

Domestic Hot Water Hourly Load Profiles



²⁰²³ ASHRAE HVAC Applications Handbook Chapter 51 Service Water Heating

Knowledge Check #1

What are some components of building energy modeling?

Building Energy Modeling

- Weather Data (location, TMY3)
- Building Occupancy
- Building Area (sf)
- Ventilation Loads (ASHRAE 62.1)
- Internal Loads (equipment, lighting, people)
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- Infiltration Loads
- Schedules (occupancy, lighting, equipment)
- Space Temperature Setpoints

Building Energy Modeling Effect on GHX Design

Peak vs. Annual Energy Loads

Monthly Load	Coo	ling 💡	He	ating
Update	Total	Peak	Total	Peak
Cancel	(kBtu)	(kBtu/hr)	(kBtu) 📋	(kBtu/hr)_
January	0	0	463087	1292
February	0	0	379962	1220
March	131	6	323065	1008
April	5366	228	171127	639
May	49673	656	0	(
June	120708	931	0	(
July	205722	1001	0	(
August	167315	879	0	(
September	84358	775	1136	88
October	1647	23	109166	422
November	0	0	268133	1077
December	0	0	404280	1491
Total:	634918	3.0 Hours at Peak	2119956	3.0 H urs at Pea
low Date				

Update	Cool	ng 📩	K Hea	
Cancel	(kBtu) 의 (kBtu/hr)	(kBtu)	(kBtu/hr)
January	0	0	176812	372
February	0	0	140719	384
March	0	0	111464	324
April	0	0	49966	232
Мау	51986	347	0	0
June	105559	417	0	C
July	150200	441	0	0
August	128065	380	0	C
September	72744	355	0	C
October	0	0	18366	163
November	0	0	98421	329
Decembe	0	0	153386	434
Total:	508554	3.0 Hours at Peak	749133	3.0 Hours at Pea

Update	Total	ling 🛃	Total	ating Peak
Cancel	(kBtu)	(kBtu/hr)	(kBtu)	(kBtu/hr)
January	0	0	417384	92
February	0	0	326140	95-
March	1686	63	250778	78-
April	6645	144	102030	54
May	112178	929	0	
June	259035	1099	0	1
July	391219	1212	0	
August	324168	1039	0	1
September	167921	988	78	1
October	19667	132	31335	30
November	0	0	223940	79
December	0	0	361744	105
Total:	1282518	3.0 Hours at Peak	1713427	3.0 Hours at Pea

Thermal Drift

COOLING DOMINANT

HEATING DOMINANT

Optimizing GHX Design

- Monthly Load Data				
Lindato	Coo	oling 🔄 🖄	🖌 🛛 Hea	ting 🔛
Opuate	Total	Peak	Total	Peak
Cancel	(kBtu) 🕘	(kBtu/hr)	(kBtu) 🕛 ((kBtu/hr) 🕛
January	164	12	276281	531
February	285	13	237738	510
March	7242	93	184659	406
April	26645	261	139124	371
May	61813	387	111848	279
June	103572	399	83513	228
July	118106	341	76349	180
August	113720	378	77641	197
September	66238	322	95590	229
October	20357	265	154153	359
November	4505	89	168428	398
December	41	5	248962	487
Total:	522688	3.0	1854286	3.0
Hours at Peak Hours at Peak				

22 500' Boreholes @ 30' OC

Optimizing GHX Design

- Monthly Load Data				
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11 800' Boreholes @ 30' OC

Optimizing GHX Design

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22 500' Boreholes @ 30' OC

Individual Building Geothermal

CASE STUDY 1 Java – Brooklyn, NY

- Mixed-use new construction
 - 800 Residential Units
 - 13,000+ sf Retail
 - Below Grade Parking
- Cooling Dominant
- 320 boreholes (500' @ 15' OC)
- Ground Source Heat Pumps (apartments and common spaces) & Electric Heat (mechanical rooms & storage rooms)
- Dry Cooler required for long term system thermal balance and performance

	Co	ooling	Heat	ing
	Total (kBtu)	Peak (kBtu/hr)	Total (kBtu)	Peak (kBtu/hr)
- January	122711	1526	1452573	6344
February	129416	1228	1292623	6864
March	249972	2739	844480	3895
April	467103	4300	596770	3098
May	983975	5889	502752	2938
June	2148772	8030	474741	2634
July	3254485	9010	489796	2633
August	2931221	8826	489523	2632
September	1570104	7241	476548	2681
October	875190	5584	567930	3423
November	220855	2197	815202	4333
December	152348	1809	1200563	4874
Total	13106151		9203501	
Hours at Peak		2.0		5.0

Knowledge Check #2

How does building energy modeling effect GHX design for an individual building?

District Geothermal Systems

District Geothermal Building Energy Modeling

Feasibility Study

- UTEN: Evaluating 20+ sites to get down to one
- Where do you begin? How much effort do you put into accurate building energy modeling?
 - Public assessors information
 - EUI factors based on occupancy and square footage

Detailed Design

- Manual J calculations
- Existing plans & site visits to build detailed energy models
- Important Characteristics for District System
 - Diversity of Loads (Commercial vs. Residential; Heating dominant vs. cooling dominant)
 - Annual balance of loads

CASE STUDY

Eversource Geothermal Pilot Project (Framingham, MA)

- 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

Identifying Customers

Building the District & Getting the Loads

TRNSYS Modeling

- Transient modeling to assess the performance of the thermal system
- Ensure customers get similar entering water temperatures along the loop
- Recharge Borefields boost temperature

Ambient Loop Temperature Distribution at the Coldest Hour of the Loop

Knowledge Check #3

How does building energy modeling effect GHX design for a district of buildings?

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Questions?

CDM Snith

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Thank you

Jacky Kinson: <u>kinsonjr@cdmsmith.com</u>, 617.452.6523

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