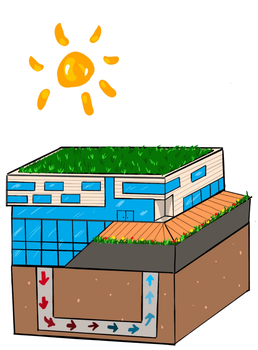
Analysis of the Proposed UMass GHX System and its Effects on Ground Temperatures

Alexander Marshall, Herlin Rijo, & Nicholas Capra

Advisors: Dwayne Breger & Benjamin McDaniel

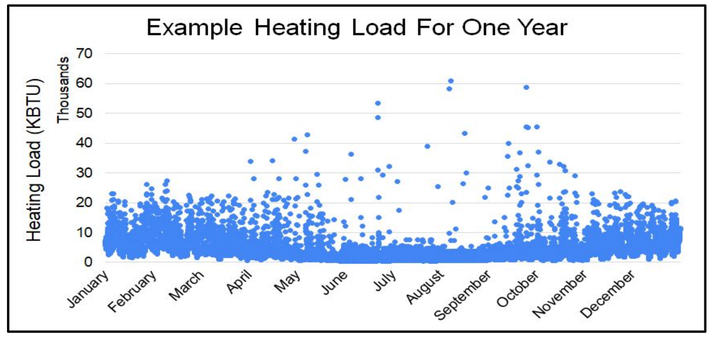
Background/Objective

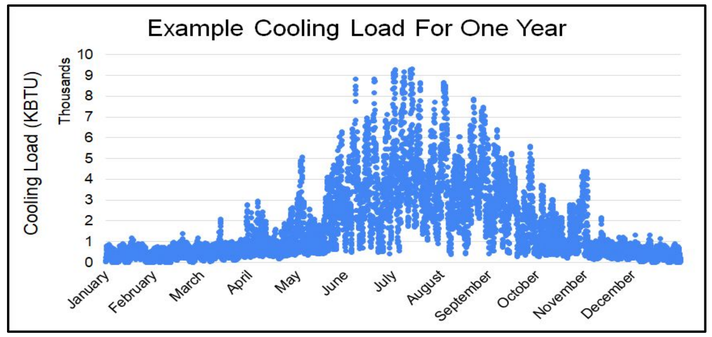
In efforts to reach carbon neutrality by the year 2032, UMass Amherst is proposing the implementation of a geothermal heat exchanger system to provide heating and cooling to campus. The objective of this project was to simulate heat transfer with a GHX system and determine the sustainability of the system. Without the UMass cooling load being completely accurate, we performed a sensitivity analysis of the system to show how ground temperatures will change with variability in cooling load.

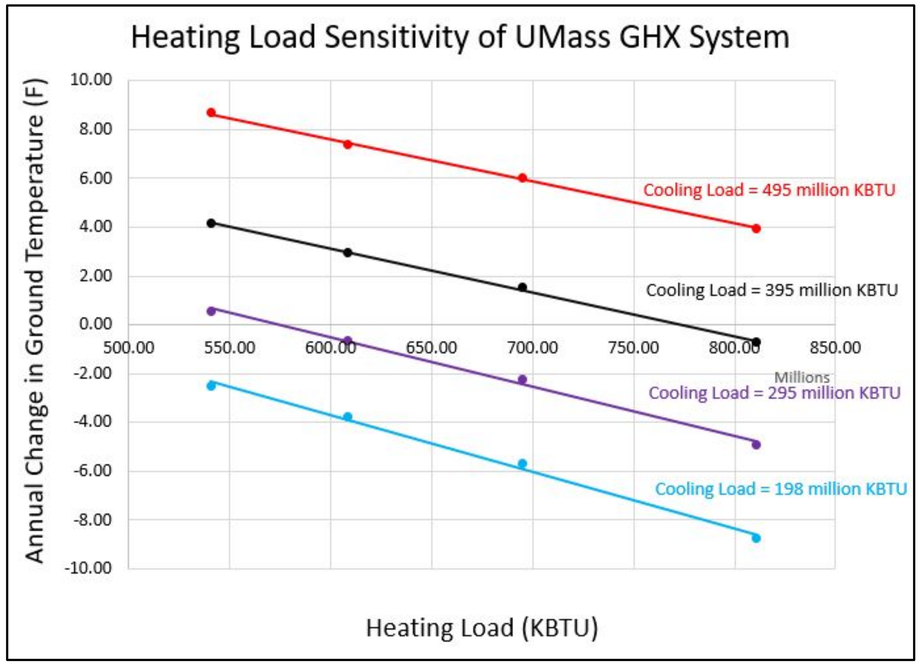


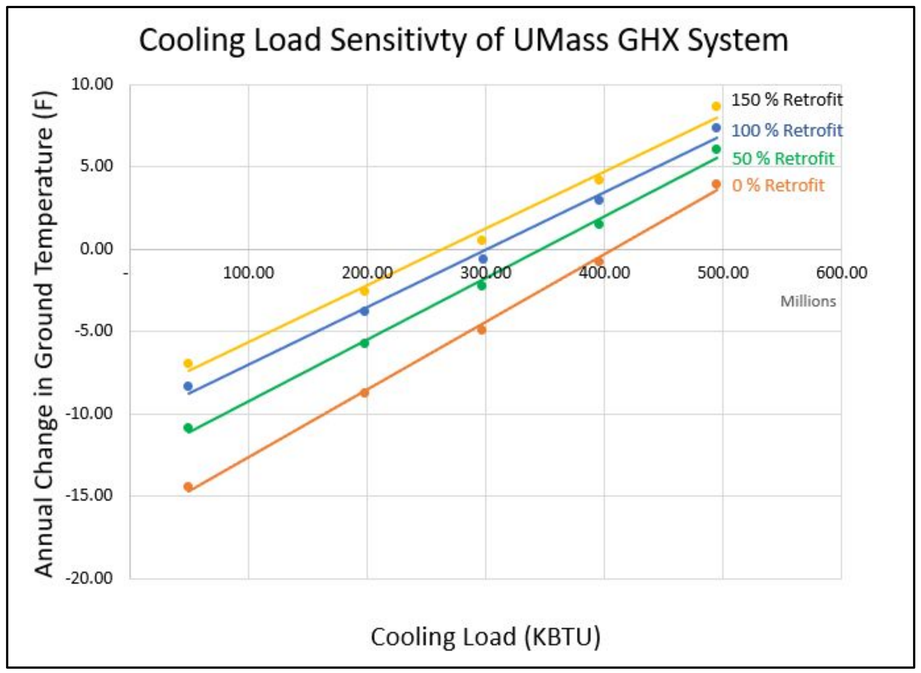
Methods/Data

- Obtained UMass heating load and arbitrary cooling load from the CMTF
- Generated hourly heating and cooling data using reopt software
- Used a TRNSYS modeling tool known as HyGCHP to model geothermal heat transfer over a 1-year period









Graph Parameters:

- Retrofitting amounts are based off of the CMTF plan to reduce the UMass heating load by around 25% by 2032
- For example, 100% retrofit refers to UMass meeting the retrofit goal and reducing the heating load by 25% whereas 50% retrofit refers to a heating load reduction of only 12.5%

Limitations/Assumptions

- Used one constant value for ground thermal conductivity
- Simulation did not allow us to fully replicate a system with the amount of boreholes listed in the CMP, so we had to scale the system linearly
- Our model was 15% of the size of the UMass system
- Only ran simulation for one year, differences in air temperature and other parameters could cause change temperature differences as the years go on
- GHX system provides 42% of UMass heating load and 51% if UMass cooling load

Conclusion

- As seen in the graphs, slight variations in cooling or heating loads can cause major disturbances to the sustainability of the system
- If current retrofit plans are met, and ideal cooling load would be around 300 million KBTU or above
- For example, a cooling load decrease of 33% results in a 490% decrease in annual ground temperature
- It is essential for UMass to continue narrowing down exact cooling loads and monitoring how the system will affect the surrounding ground temperatures

Future Directions

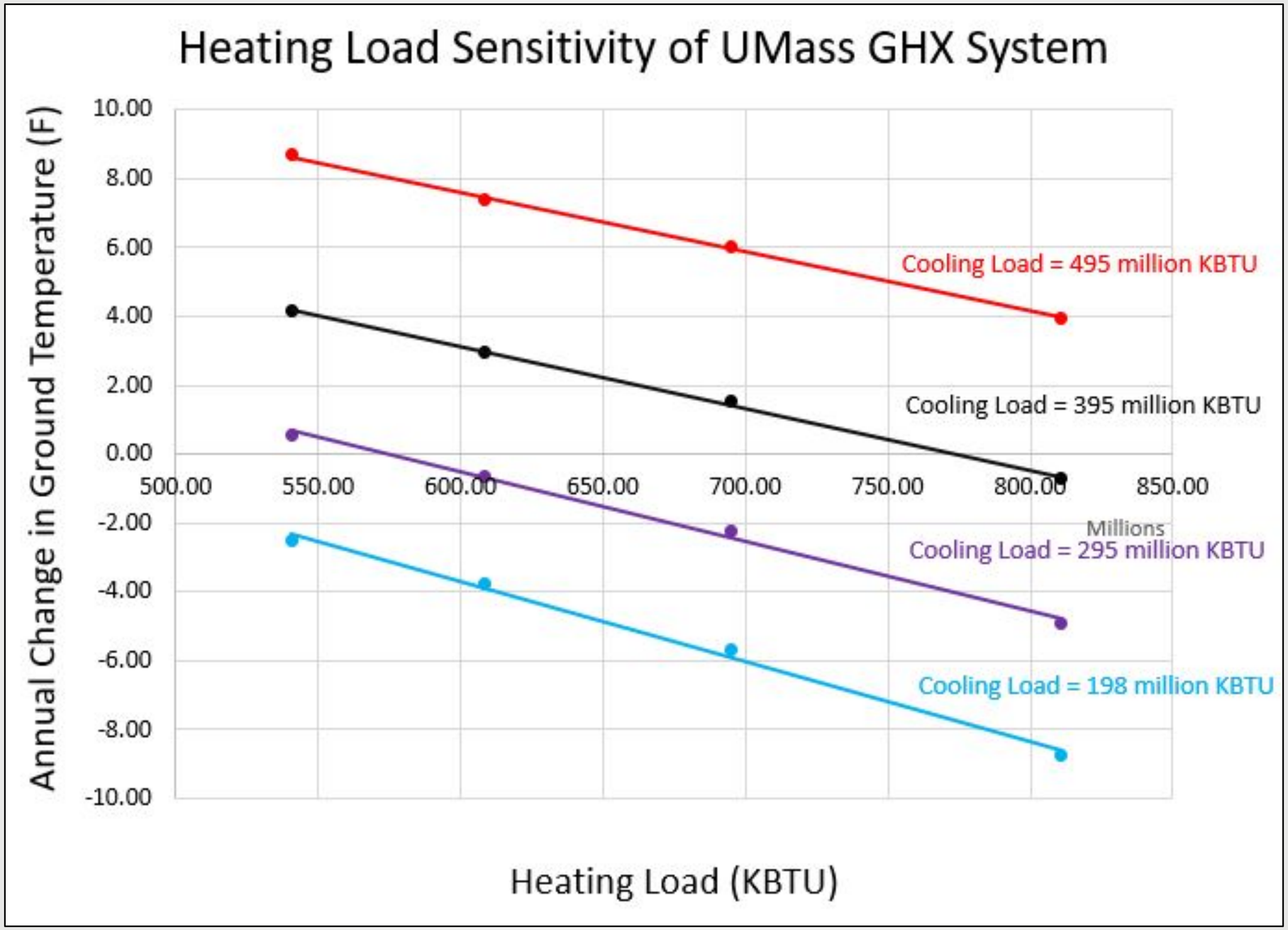
- Gather more information on the necessary data points such as the actual campus cooling loads and geological impact of the environment beneath the ground on the system
- Analyze the system over many years to see if annual temperature changes vary with how long the system has been running
- Use a software that allows for a larger system size and more parameter adaptations to get a better understanding of the systems effects on ground temperatures
- Look into supplemental heating technologies that could allow the system to provide more heat to campus

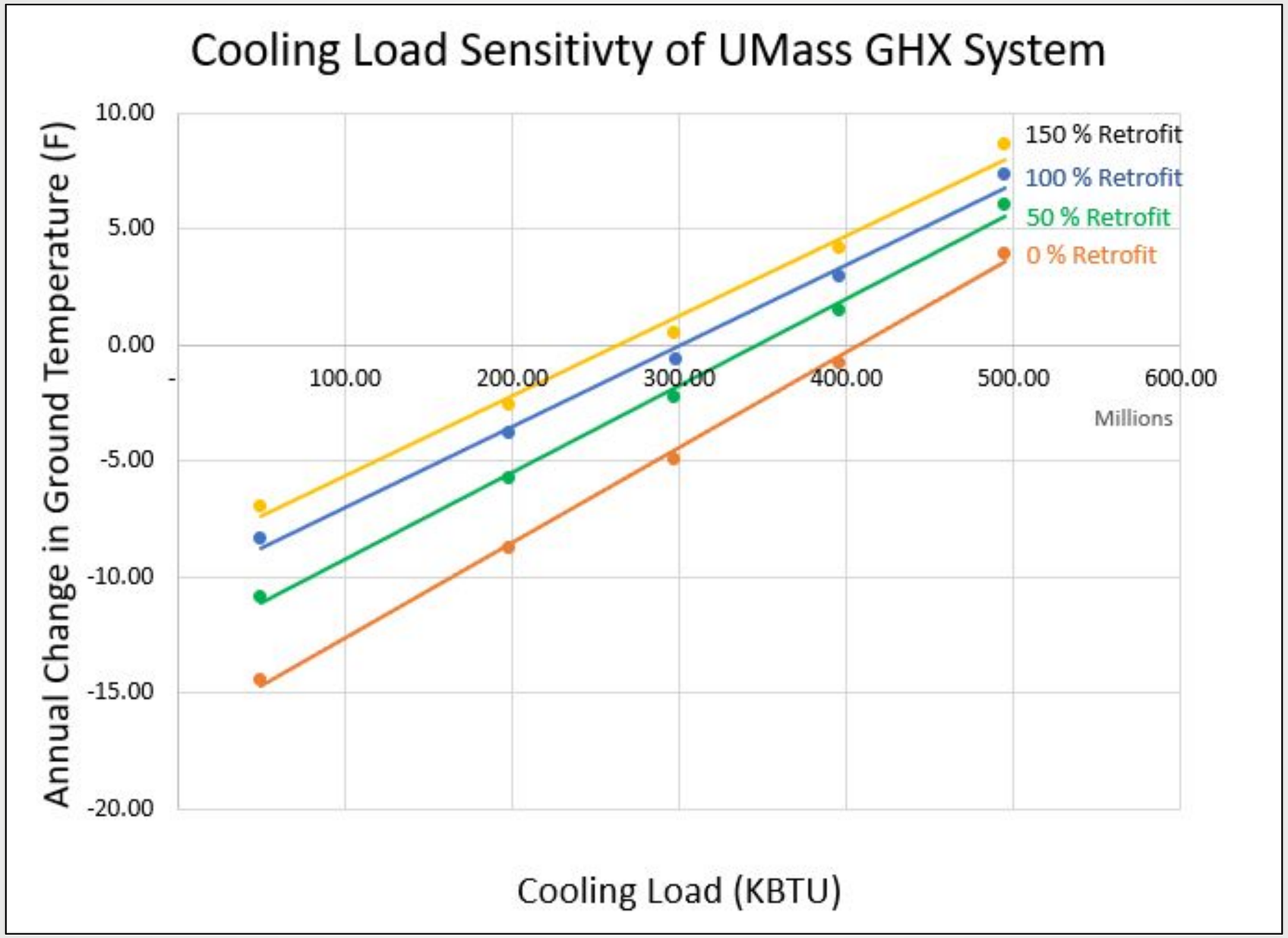
References/Acknowledgments:

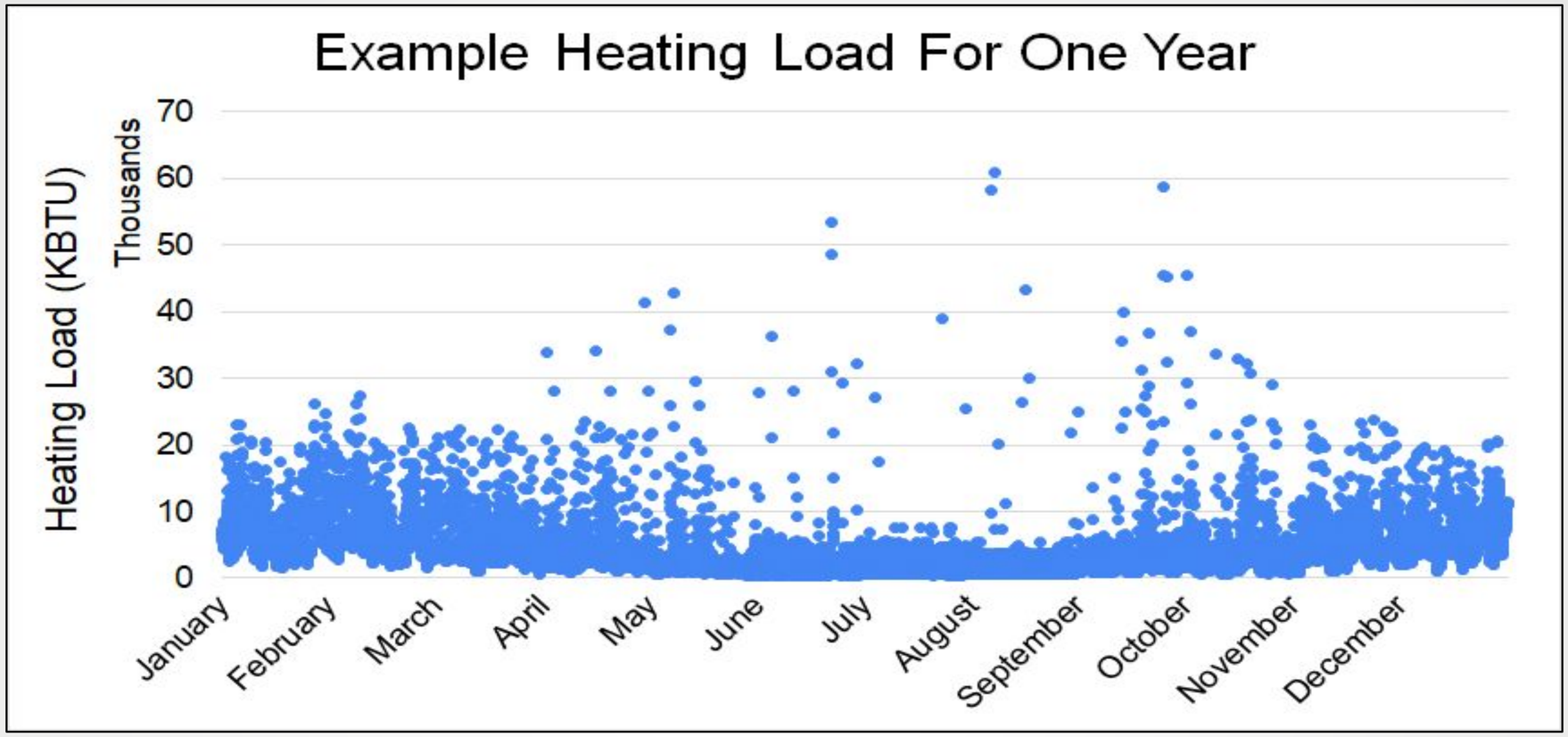
- Heating load and GHX system data obtained from the Carbon Mitigation Task Force
- Special thanks to our advisors and iCons 3E professors who guided us to success on this project

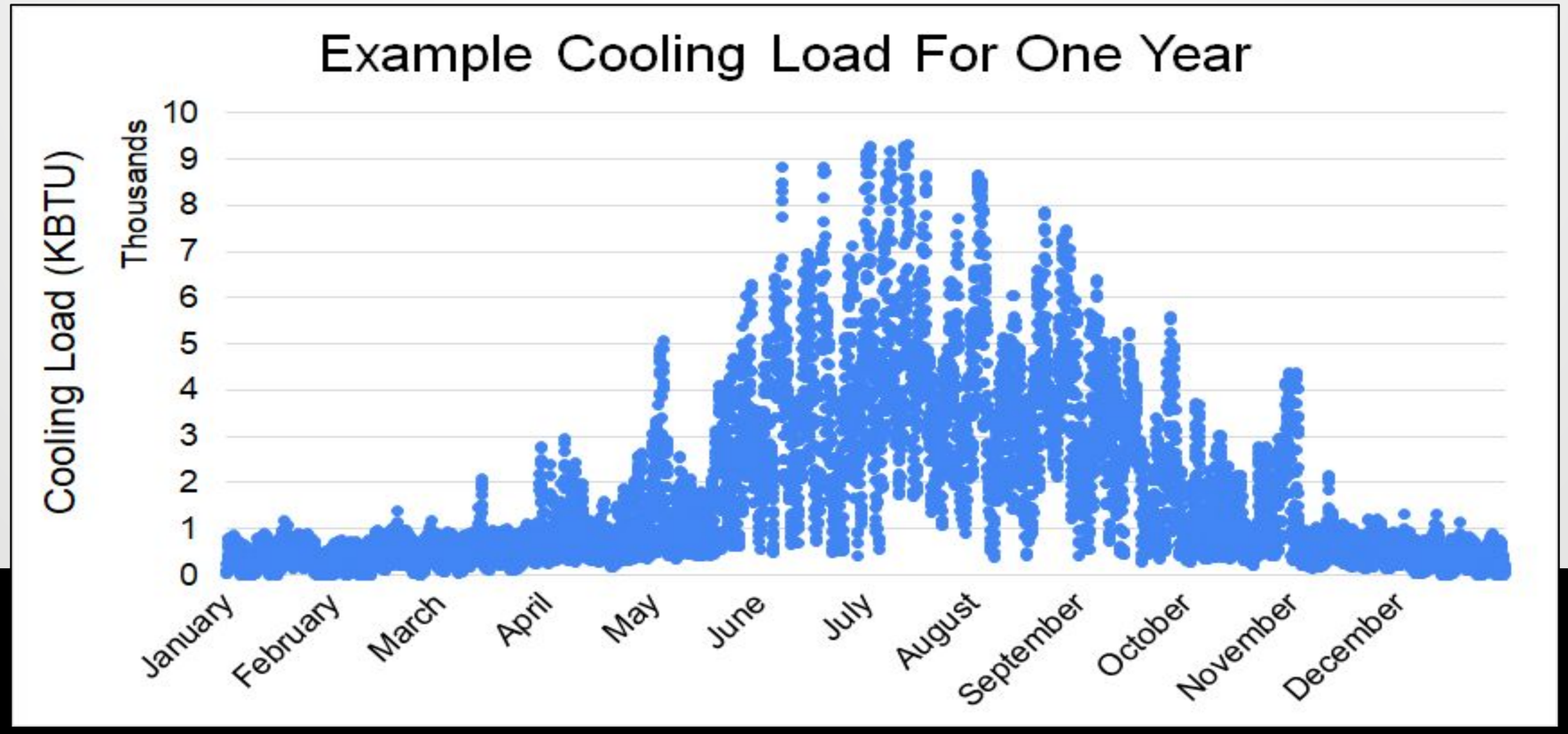
We thank sponsors of iCons and our research:

Mahoney Family Sponsorship


Heating Load Sensitivity of UMass GHX System
Annual Change in Ground Temperature (F)
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
500.00
550.00
600.00
650.00
700.00
750.00
800.00
850.00
Millions
Cooling Load = 495 million KBTU
Cooling Load = 395 million KBTU
Cooling Load = 295 million KBTU
Cooling Load = 198 million KBTU
Heating Load (KBTU)


Cooling Load Sensitivty of UMass GHX System
Annual Change in Ground Temperature (F)
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
100.00
200.00
300.00
400.00
500.00
600.00
Millions
150 % Retrofit
100 % Retrofit
50 % Retrofit
0 % Retrofit
Cooling Load (KBTU)


Example Heating Load For One Year
Heating Load (KBTU)
Thousands
70
60
50
40
30
20
10
0
January
February
March
April
May
June
July
August
September
October
November
December


Example Cooling Load For One Year
Cooling Load (KBTU)
Thousands
10
9
8
7
6
5
4
3
2
1
0
January
February
March
April
May
June
July
August
September
October
November
December