Hack-Homewood 2021: The Laboratory Sustainability Challenge

Background:

As one of the foremost research institutions, Johns Hopkins dedicates many spaces to research. However, research can be energy intensive. As the Office of Sustainability states, "labs typically account for 70% of the institution's carbon footprint and use four times more energy per square foot than other university spaces." Yet, labs only account for about 30% of the university's floor space.[1]

A large portion of a lab's energy usage is due to its freezers. Over the course of a year, the average lab freezer uses the same amount of energy as the average American home.[2] With over 1,000 freezers across both Homewood campus and the Medical campus, the University spends almost $2 million annually on energy for freezers alone. Reducing energy use in freezers would be beneficial both for the University's carbon footprint and its wallet (Figure 1,2).

As freezers age, even with good maintenance, they tend to consume more than 3% more energy every year (Figure 3). A twenty year old freezer uses over 75% more energy than when the freezer was newly acquired. Extra heat older freezers generate due to their high energy usage causes HVAC systems to work harder to keep lab temperature at a nominal level. Considering the HVAC factor, 20 year old freezers can cost significantly more in energy each year than 5 year old freezers (Figure 3, 4).

A correlated issue is that researchers seek to maximize their grant money when they buy freezers. So, they buy cheaper, inefficient freezers. Moreso, individual labs are not responsible for the energy use of these freezers. Therefore, no incentive exists for labs to buy more efficient freezers. An initiative at the University of Pennsylvania to reduce freezer costs provides labs with monetary incentives to buy more efficient freezers and recycle old freezers.[3]

Underutilization of freezer space is also a problem that, if resolved, could drastically reduce energy use. Freezers filled to capacity are inherently more energy efficient, and many labs do not fill their individual units to capacity. For example, the University of Colorado Boulder has shared lab spaces with communal equipment.[4] These shared spaces can then allocate resources, specimens, and equipment to labs based on need. Equipment like freezers in these spaces see higher utilization, and since less freezers are required, more money can be spent on buying highly efficient freezers to cut energy usage.

An easy way to reduce freezer energy consumption is by simply educating PIs. An example is reducing -80C freezers to -70C since there is no impact on specimen life but energy use is reduced.[4] Also, filling freezers as much as possible ensures freezers stay cold when opened to minimize compressor use (Figure 5).

In consideration of the above sustainability issue, solutions submitted are expected to reduce energy cost for the university, be realistically implementable, demonstrate compatibility with laboratory workflows, and be viable long-term.

Solution Criteria and Specifics

Cost Reduction:
Most important to the University is the potential to reduce energy costs. Due to the predictable nature of freezer wear and tear, it is estimated that for each year of use, a freezer becomes 3% more inefficient. Currently, freezer purchases are made on a lab-by-lab basis. Principal investigators (PIs) generally choose the cheapest freezer with the largest volume. Because the University pays for but does not monitor individual lab energy usage, there is currently no incentive for labs to choose a more expensive, energy efficient freezer or to replace an old unit. At the medical campus alone, it is estimated that an extra $2 million is spent each year on excess energy used by inefficient freezer units, some of which are more than 20 years old.

In addition, the use of existing freezers is not optimized. While there have been university-wide campaigns to educate labs about best practices for ULT freezers such as filling to maximum capacity, regular cleaning, and reducing time open, high turnover in lab managers and workers, and lack of centralization for freezer monitoring have rendered efforts relatively ineffective thus far. The best solution to reduce costs will be multifaceted. Factors to consider when developing your own solution include: replacing old units, incentivizing the purchase of energy efficient new freezers, ensuring efficient use of space in units, and educating labs about best practices.

Implementability:
The end goal of the case competition is to present the winning solution to University administration. In order for a solution to be viable, a realistic implementation plan must be considered. While this is an overarching criterion, the best solution will be actionable in the scale of several months and will consider factors such as required initial investment, how much manpower would be required to execute, how training/education initiatives will be distributed, and how much oversight will be required for implementation and in the long term. A major component of any solution involves PI buy-in. Without support from the labs themselves, a solution will not succeed. Consider what, if any, incentive (financial or otherwise) labs might be given to partake in improving freezer efficiency.

Compatibility with Existing Workflow:
While the case competition's goal is to reduce energy usage in labs for the university's benefit, PIs will experience the brunt of any proposed changes. Therefore, a viable solution must be compatible with current laboratory workflows. This requirement is difficult to

implement due to the vastly different setups labs can have. However, a strong solution must be considerate of all PIs' time. Factors to examine include how the current workflow looks, how much time would a PI have to spend implementing this solution, how this solution would change lab workflows, and how much extra cost is required to make the solution compatible with the PI's workflow.

Longevity:
An area of difficulty previous solutions ran into was long term effectiveness. Previous efforts made, such as the Green Labs challenge initiative last year, saw labs fill out forms making promises to improve the sustainability and efficiency of ULT freezers. However, as time progressed, there was little follow through with promises made since the trouble to go through (e.g. having to find a place to store samples for the time during freezer upgrades or adjustments) was greater than the individual benefit. PIs and lab members will not implement solutions if there is difficulty in communicating or demonstrating a financial or environmental benefit to their labs. Therefore, a solution must address short term implementation as addressed above, and must outline a clear plan for long-term system maintenance to increase retention, which would likely include an incentive for the PI. Longevity of the solution itself without relying on the PI or lab members directly is critical as there is significant turnover of faculty year-to-year.

Trade-offs:
As no solution will be able to address all aspects of a problem perfectly, a solution must be designed taking into account all sides of the issue and the impact of each element. Therefore, a solution must include a breakdown of the tradeoffs or a cost benefit analysis of the solution versus current methods of lab refrigeration. This breakdown should address the above categories of cost, implementability, lab workflow, and longevity. When considering this, the breakdown should take into account the impact on individual lab members (ie. lab techs, graduate students, post docs, undergraduates, etc.), PIs, the university as a whole, and the larger Baltimore and Maryland research community.

Sources:
https://sustainability.jhu.edu/initiatives/buildings-infrastructure-initiative/
https://www.mygreenlab.org/
https://sustainability.upenn.edu/sites/default/files/FRES%20ULT%20Freezer%20Infomation%2011%2030%202018_0.pdf
https://www.colorado.edu/ecenter/sites/default/files/attached-files/ucr_ult_tests_report_-_2016_final_df1.pdf

Cost Benefit Framework

Costs	
Category	Total
Initial Solution Installation	
Long-Term Solution Maintenance	
Disruptions to PI Workflow	
Cost to JHU for Resource Diversion	
Potential Additional Costs	
Benefits	
Category	Total
Energy Savings	
Environmental Benefits	
Reduced Maintenance	
Increase in Lab Space due to Removal of Old Freezers	

Using this framework, create an evaluation of your solution based upon these categories and add categories to the Cost-Benefit Analysis as needed based on your team's solution. This is a good resource to read for more information about cost-benefit analyses. Please include a brief justification of each cost and benefit.

Submission Format

(1) 1 page single spaced
 (a) 11 font, Times New Roman or Arial
 (b) Include sources on second page
(2) 5 minute recorded video presentation
 (a) Slide deck
 (b) Include sources slide

Judging Rubric

Separate File

Appendix

JHU Data for Reference:

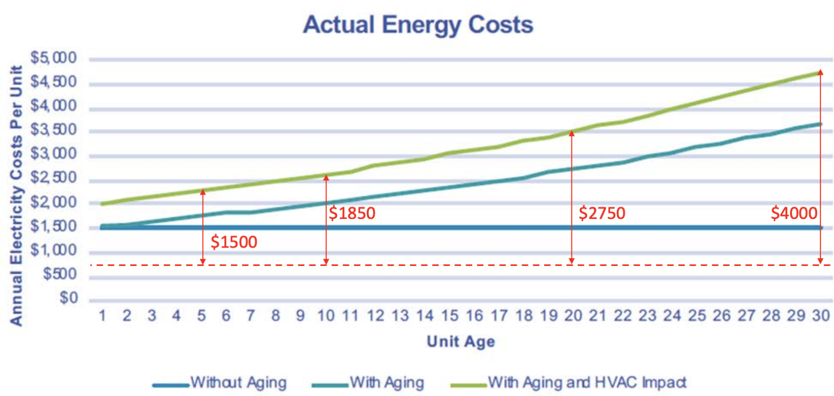


Figure 1

Estimate of extra energy cost associated with aging freezer units, by year in use.

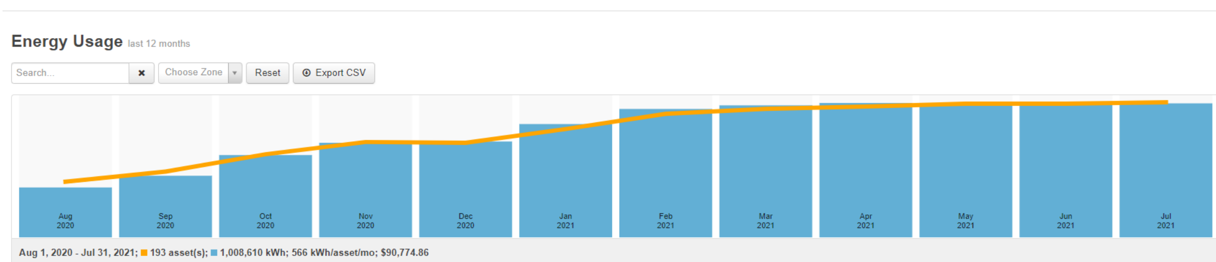


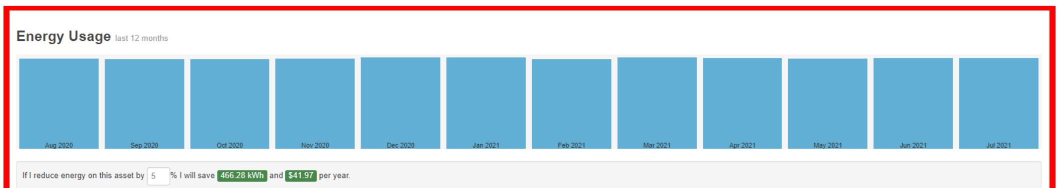
Figure 2

Aggregate energy usage for the 193 freezers in the JHSPH InSight monitoring program. Over the 12 months, more freezers were introduced into the program. In total, 1,008,610 kWh were used. On average, an individual freezer used 566 kWh per month. This resulted in a total energy expenditure of $90,774.86 over the year for just these select freezers, assuming $0.09 per kWh.

COUNTS	#Freezers	Extra energy cost/Freezer	Total extra annual cost
0-5yrs	441		
5-10yrs	417	$1,500	$625,500
10-15yrs	264	$1,850	$488,400
15-20yrs	183	$2,750	$503,250
>20yrs	74	$4,000	$296,000
total	1379		$1,913,150

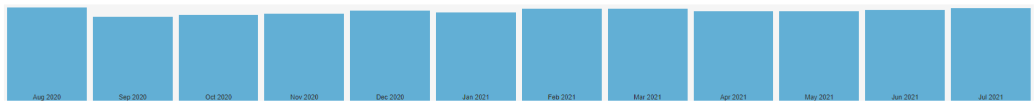
Figure 3

Extraneous energy costs due to increased inefficiencies as freezers age from a study of freezer use at the Johns Hopkins Hospital. Each year that a freezer is run, efficiency decreases by ~3%. Over time, this leads to extra energy costs on top of the cost of the freezers energy use at maximum efficiency (i.e. the first year). These figures can be used as a small sample for the costs of freezer aging across the university.



Month	kWh/day	kWh/ft^3/year	$/ft^3/year	kWh/year	$/year	Change
Jul 2021	25.72	-	-	9,387	$844.88	+0.31%
Jun 2021	25.64	-	-	9,358	$842.25	+0.65%
May 2021	25.47	-	-	9,297	$836.79	-0.76%
Apr 2021	25.67	-	-	9,368	$843.21	-0.43%
Mar 2021	25.78	-	-	9,409	$846.84	+2.04%
Feb 2021	25.26	-	-	9,220	$829.88	-2.10%
Jan 2021	25.80	-	-	9,418	$847.65	+0.11%
Dec 2020	25.78	-	-	9,408	$846.74	+1.00%
Nov 2020	25.52	-	-	9,315	$838.36	+1.09%
Oct 2020	25.24	-	-	9,214	$829.30	+0.16%
Sep 2020	25.21	-	-	9,200	$828.01	-1.02%
Aug 2020	25.47	-	-	9,295	$836.58	-

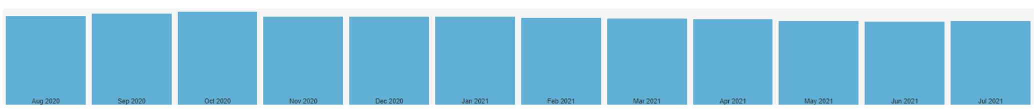
Energy Usage last 12 months



If I reduce energy on this asset by 5 % I will save 310.62 kWh and $27.96 per year.

Month	kWh/day	kWh/ft^3/year	$/ft^3/year	kWh/year	$/year	Change
Jul 2021	17.68	267.77	$24.10	6,453	$580.79	+2.14%
Jun 2021	17.31	262.16	$23.59	6,318	$568.63	+1.25%
May 2021	17.10	258.93	$23.30	6,240	$561.63	+0.20%
Apr 2021	17.06	258.43	$23.26	6,228	$560.53	-2.43%
Mar 2021	17.49	264.87	$23.84	6,383	$574.51	-0.29%
Feb 2021	17.54	265.64	$23.91	6,402	$576.18	+3.92%
Jan 2021	16.88	255.62	$23.01	6,160	$554.44	-1.61%
Dec 2020	17.15	259.79	$23.38	6,260	$563.49	+3.36%
Nov 2020	16.60	251.36	$22.62	6,057	$545.19	+1.60%
Oct 2020	16.33	247.40	$22.27	5,962	$536.60	+2.01%
Sep 2020	16.01	242.52	$21.83	5,844	$526.03	-9.90%
Aug 2020	17.77	269.17	$24.22	6,486	$583.82	-

Energy Usage last 12 months



If I reduce energy on this asset by 5 % I will save 140.39 kWh and $12.63 per year.

Month	kWh/day	kWh/ft^3/year	$/ft^3/year	kWh/year	$/year	Change
Jul 2021	7.39	107.96	$9.72	2,699	$242.91	+0.79%
Jun 2021	7.34	107.12	$9.64	2,678	$241.02	-0.74%
May 2021	7.39	107.91	$9.71	2,697	$242.81	-2.00%
Apr 2021	7.54	110.11	$9.91	2,752	$247.76	-0.57%
Mar 2021	7.59	110.75	$9.97	2,768	$249.18	-1.21%
Feb 2021	7.68	112.11	$10.09	2,802	$252.24	-1.05%
Jan 2021	7.76	113.29	$10.20	2,832	$254.91	-0.54%
Dec 2020	7.80	113.91	$10.25	2,847	$256.29	+0.52%
Nov 2020	7.76	113.32	$10.20	2,832	$254.97	-5.50%
Oct 2020	8.21	119.92	$10.79	2,997	$269.81	+2.21%
Sep 2020	8.04	117.33	$10.56	2,933	$263.99	+2.38%
Aug 2020	7.85	114.61	$10.31	2,865	$257.86	-

Figure 4

Energy consumption data from a low, medium, and high efficiency freezer unit in the InSight monitoring program.

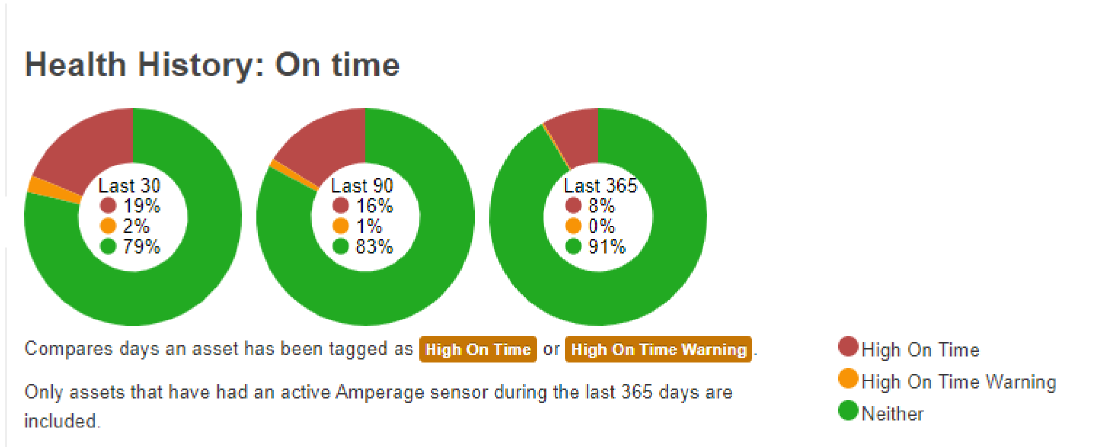


Figure 5

Health of compressor units over the last year, 90 days, and 30 days for freezers in the JHSPH InSight program. High on time refers to the amount of time that a compressor operates in a given freezer. Freezers that have high "on time" are very likely to be older, inefficient freezers.

Resources for Participants

Green Lab Resources
Freezer Challenge
JHU Sustainability Initiatives
Laboratory Benchmarking Tool
JHU Genetic Resource Core Facility
Cost Benefit Analysis Guide
CU Boulder Green Labs
UMN Freezer Practices
NIH Freezer Challenge
Stanford Energy Initiatives
UCSF Freezer User Guide
Energy Efficient Freezer Benefits