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From the Grounds Up

PILOTING SUSTAINABILITY IN UVA RESEARCH LABS

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SUSTAINABILITY AND GREEN LABS AT THE UNIVERSITY OF VIRGINIA

Founded in 1819 by Declaration of Independence author Thomas Jefferson, the University of Virginia is known for its rich history, but also for its high impact research. Considered an R1 Doctoral University, UVA has the highest possible research activity rating with a Principal Investigator population of approximately 520 scientists.

> In 2013, UVA founded its Office for Sustainability (OFS), and later in 2016, the Green Labs Program, illustrating a commitment to lowering greenhouse gas emissions and the environmental impact of research performed on our campus.

Now, in 2018, the University is home to 52 Leadership in Energy and Environmental Design (LEED) Certified campus buildings and has a STARS Gold rating from the Association for Advancement of Sustainability in Higher Education (AASHE). Despite continued growth in both square footage and personnel, UVA's sustainability programing has realized a 19% reduction in greenhouse gas (GHG) emissions since 2009. Still, the University faces a unique set of challenges moving forward, especially in the improvement of lab buildings and lab operations. UVA research labs take up only 9% of the University's physical footprint but are responsible for a quarter of its energy consumption. Some of UVA's 34 research departments are making ground-breaking discoveries in century-old buildings while others work in technologically advanced spaces constructed as recently as 2011. Furthermore, the quantity and diversity of departments and scientific fields of study on our campus introduces numerous variables to our campus system, making streamlined safety and sustainability initiatives a challenge. Despite these challenges, continued advancement in the sustainable research sector will be of the utmost importance as UVA reaches for a 25% GHG reduction by 2025 (UVA Sustainability Plan, 2016).

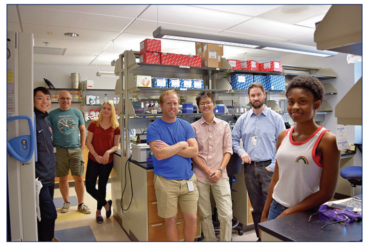
CAMPUS AS A LIVING LAB FOR BUILDING RELATIONSHIPS WITH THE LOCAL RESEARCH COMMUNITY

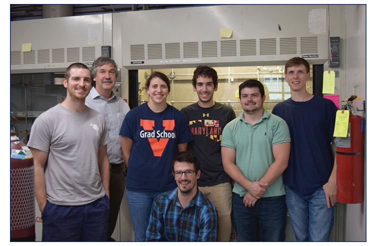
Approaches to lab sustainability in higher education tend to address either wasteful buildings (via upgrades in lighting, temperature setbacks, occupancy sensors, improved mechanical systems etc.) (Bell et al., 2003; Labs21, 2001; Lawhon, 2012) or inefficient occupant behaviors (via freezer set-points, benchtop equipment settings, posted reminders for best practices etc.) (Bell, 2012; Michetti, 2016; My Green Lab, 2017). While building-level changes offer quick and reliable paybacks, they are often expensive and neglect opportunities to educate occupants on safety standards, work-flow efficiency, and other beneficial practices. Similarly, only focusing on occupant-based programs would exclude necessary renovations for maximizing efficiency and building longevity while simultaneously connecting researchers to the built environments in which they work.

> Our "Pilot Lab Program" sought to combine both approaches and study the true potential of holistic Green Labs programing that addresses both building and user aspects of research efficiency.

A Pilot Program Team, comprised of an Energy Engineer to address building changes and a Green Labs Specialist to lead occupant changes, identified three Program Partners: the Hammarskjöld – Rekosh Lab (Microbiology and Immunology), the Civelek Lab (Systems Genetics), and the Harman Lab (Synthetic Chemistry). These three groups came from diverse scientific fields and varied arrangements of personnel density, physical space, equipment types, and therefore baseline energy intensities, detailed in Table 1.

TABLE 1. ENERGY INTENSITY PROFILES OF THREE PILOT LABS PARTICIPATING IN THE PILOT LAB PROGRAM





ATTRIBUTE	HAMMARSKJÖLD – REKOSH (HAM – REK)	CIVELEK	HARMAN
LAB/RESEARCH CLASSIFICATION	MICROBIOLOGY/ IMMUNOLOGY LAB	SYSTEMS GENETICS LAB (BIOLOGY-BASED)	SYNTHETIC CHEMISTRY LAB
BIOSAFETY LEVEL	BSL2	BSL1	BSL2
POPULATION	18 ACTIVE MEMBERS	8 ACTIVE MEMBERS	10 ACTIVE MEMBERS
FOOTPRINT	1650 SQ. FT. ACTIVE LAB SPACE, 1075 SQ. FT. SUPPORT SPACE	700 SQ. FT. ACTIVE LAB SPACE, 150 SQ. FT. SUPPORT SPACE	1380 SQ. FT. ACTIVE LAB SPACE, 645 SQ. FT. SUPPORT SPACE
COLD STORAGE CENSUS	TWO ULTS AT -80°C, ONE UPRIGHT FREEZER AT -40°C, THREE UPRIGHT FREEZERS AT -20°C, ONE SMALL CHEST FREEZER AT -20°C, ONE FREEZER/REFRIGERATOR COMBO AT 4°C TO -20°C, AND ONE XL UPRIGHT REFRIGERATOR	(COLD BANK) AT 4°C TWO ULTS SET TO -80°C, ONE UPRIGHT FREEZER SET TO -20°C, AND ONE UPRIGHT REFRIGERATOR SET TO 4°C	TWO UPRIGHT FREEZERS SET TO -30°C, ONE -20°C UPRIGHT FREEZER, AND ONE 5°C REFRIGERATOR
OTHER NOTABLE LARGE PIECES OF EQUIPMENT	LARGE INCUBATOR-SHAKER, LARGE CENTRIFUGE FOR 1L BOTTLES, TWO BENCHTOP INCUBATOR/OVENS	GEL IMAGER AND LARGE CENTRIFUGE	SHIMADZU GCMS, -80°C COLD PROBE, ROTOVAP CONDENSERS, FOUR DRYING OVENS
# CHEMICAL FUME HOODS	THREE CONSTANT AIR VOLUME	ONE VARIABLE AIR VOLUMENINE	VARIABLE AIR VOLUME
# AIR CHANGES PER HOUR	11.2	13.2	14.7
INSTALLED VS. AVG. LIGHTING POWER DENSITY	1.81 WATTS / SQ. FT. TO 1810 WATTS	1.49 WATTS / SQ. FT. TO 690 WATTS	1.15 – 2.4 WATTS / SQ. FT. TO 1610 WATTS

Creating a Program Framework (Figure 1) was essential for ensuring that all involved partners had a clear view of how the Pilot Program would proceed and what was expected of all parties. However, partners could adapt the Framework as needed, with the understanding that each group would have separate scheduling needs, material sensitivities, and maintenance crews working within different University zones. Two of our Pilot Labs are part of UVA's School of Medicine, while the Harman Lab in the Chemistry Department is part of the College of Arts and Sciences. This seemingly minor difference introduced multiple campus zones, their managers, maintenance teams, and different renovation crews, meaning that the same task, such as changing faucet aerators, required coordination with three different groups. Other academic research institutions adopting a similar approach to data-gathering may experience similar circumstances. Collecting data from a diverse population results in diverse obstacles, successes, and outcomes.

Even so, staying true to UVA Sustainability Plan goals and utilizing our campus as a living lab was an essential means for building relationships with the local research community and gathering energy use data accurately reflecting our lab population (Gilly, 2016; Greever et al., 2018; Hafer, 2015). Successful space optimization and implementation of best practices model a positive example for other campus research groups while providing data to OFS intended to inform the direction of future Green Labs initiatives. Furthermore, connections and relationships with the variety of maintenance and facilities crews developed through the Pilot Lab Program laid a foundation for initiatives that may be optimized and carried out across multiple zones in the future.

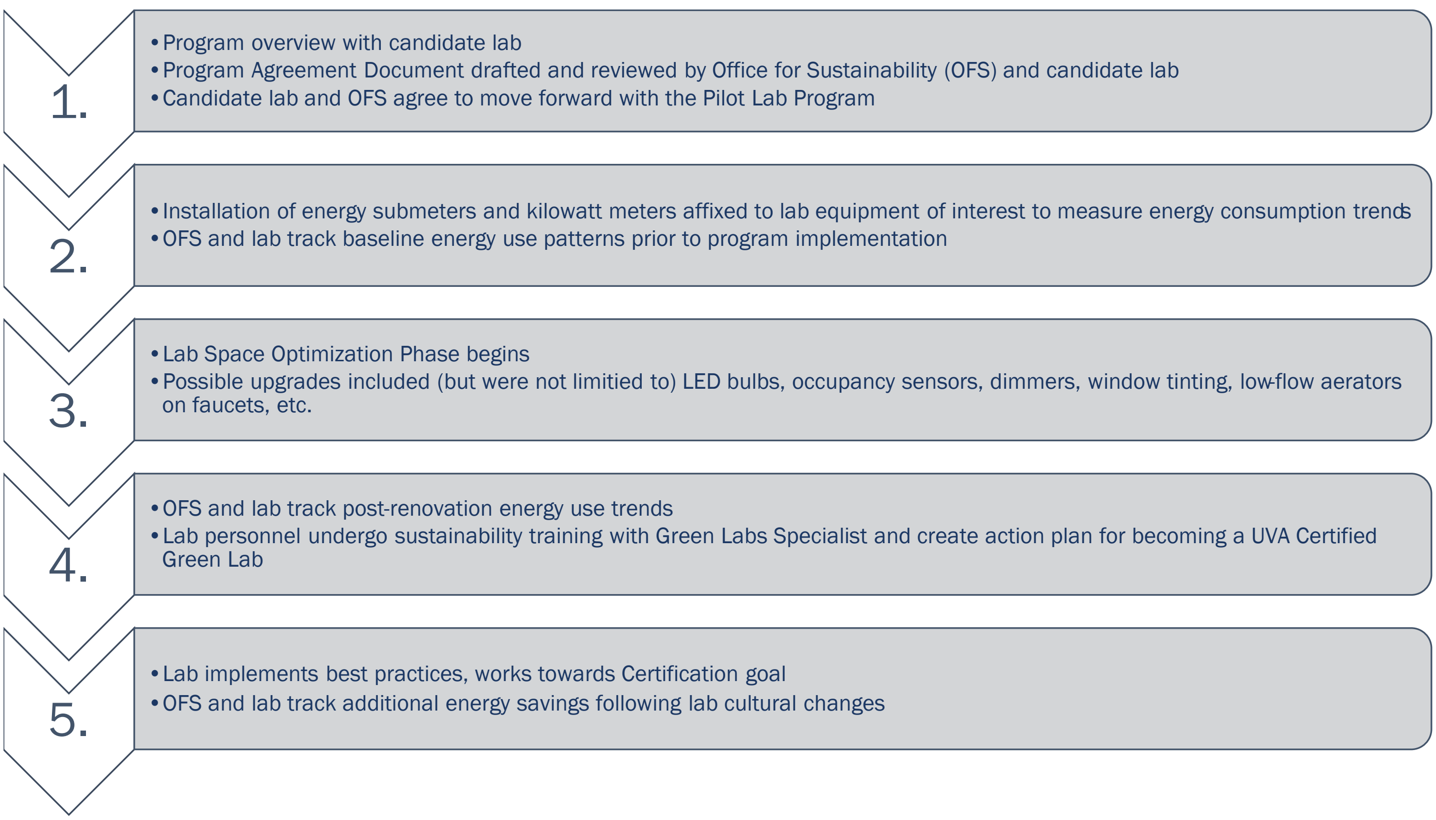


Figure 1. Pilot Lab Program Framework, a projected timeline of events

PROGRAM IMPLEMENTATION

In each lab, energy submeters were first installed to establish baseline energy intensity, after which built space and cultural changes commenced and subsequent savings were measured. Changes included but were not limited to: installation of energy-efficient LED lights, window film application, occupancy sensor installation, Green Labs sustainability training for personnel, and development of a Green Labs Certification action plan for implementing best practices. Training and action plans focused on safety and efficiency opportunities such as shutting the chemical fume hood sash, warming ultra-low freezer setpoints from -80 to -70°C, applying timers to day-use benchtop equipment (ex. water baths, drying ovens), and more. Figures 2, 3, and 4 illustrate the timepoint a sustainability improvement was introduced and the corresponding energy intensity. In some cases, we observed little to no change while other actions resulted in significant reductions. Furthermore, changes made across all three Pilot Labs did not yield the same results in every space.

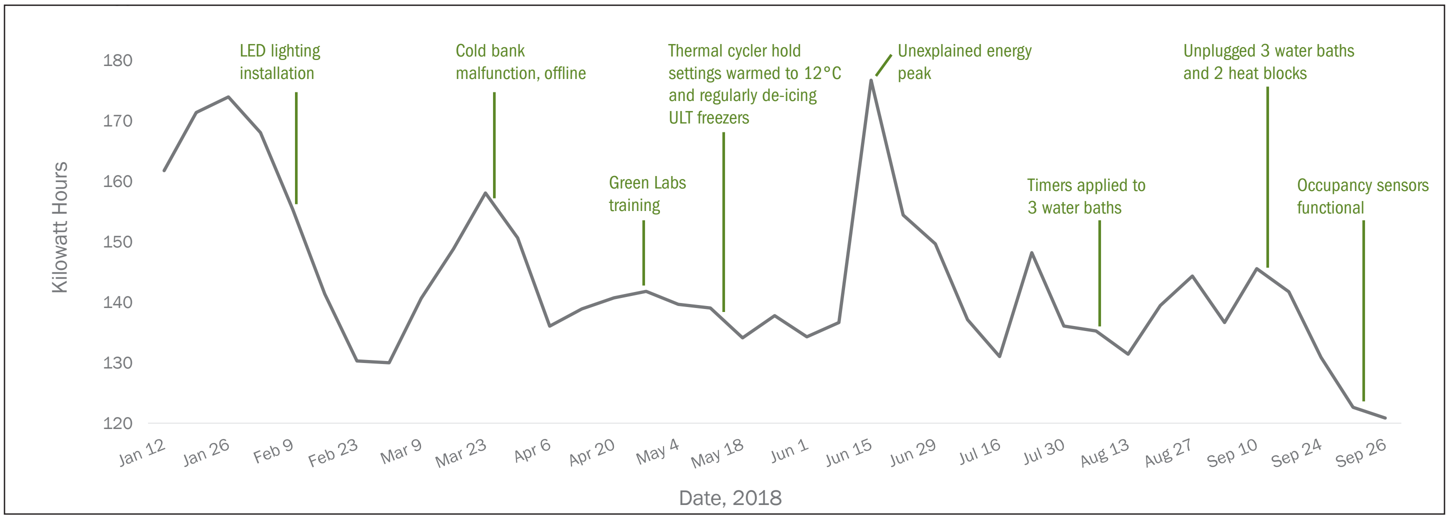


Figure 2. Weekday average electricity usage in the Hammarskjöld – Rekosh Lab in relation to sustainability actions undertaken as part of the Pilot Lab Program, 2018

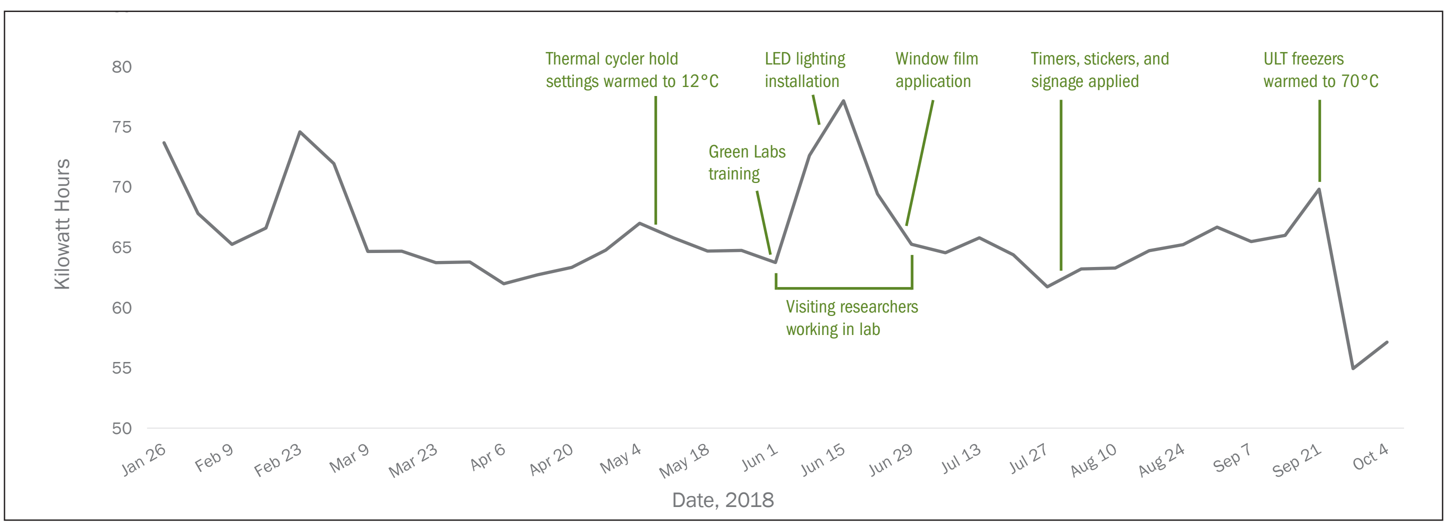


Figure 3. Weekday average electricity usage in the Civelek Lab in relation to sustainability actions undertaken as part of the Pilot Lab Program, 2018

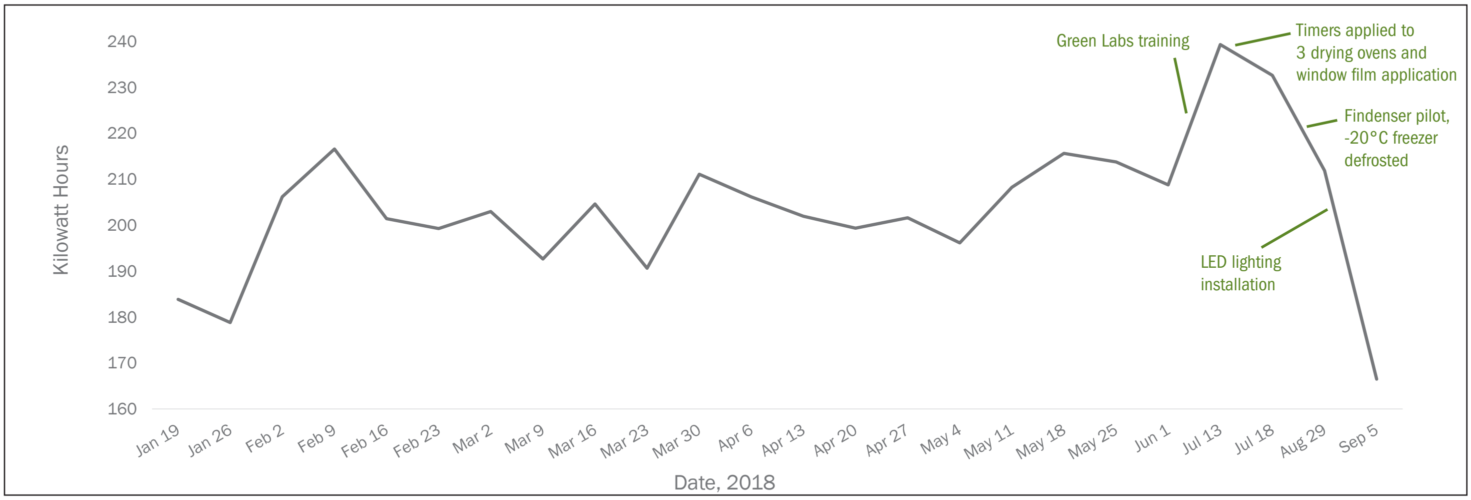
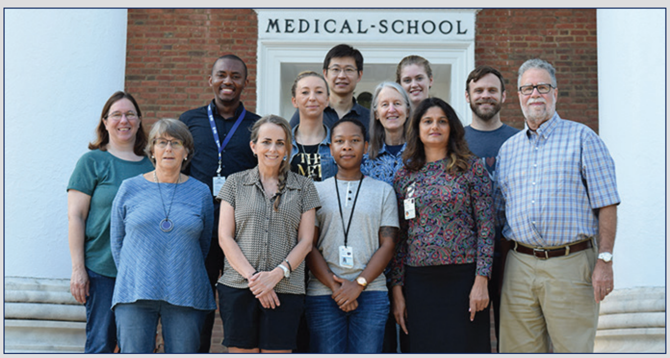


Figure 4. Weekday average electricity usage in the Harman lab in relation to sustainability actions undertaken as part of the Pilot Lab Program, 2018

RESULTS

BIG WINS FOR THE HAMMARSKJÖLD – REKOSH LAB: LED LIGHTING



The Ham – Rek lab was our largest lab across almost all attributes including square footage, lab population, and lighting power density. As expected, renovating the outdated light fixtures was a boon for energy savings, cutting lighting energy costs by more than half (56.7% reduction in lighting energy consumption). The application of timers on benchtop equipment contributed additional savings and the lab saw a 14% reduction of their carbon footprint overall.

Maximizing return-on-investment from lighting occupancy sensors in academic research labs:

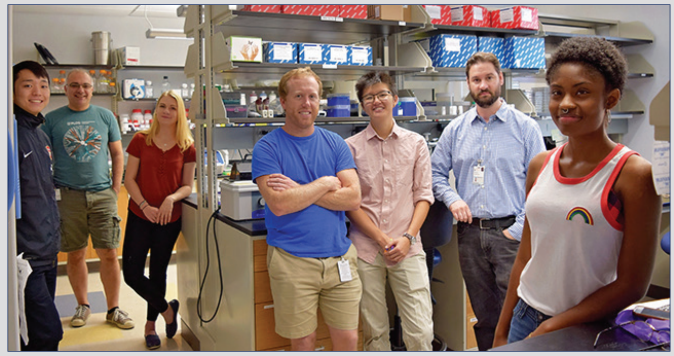
Lighting constitutes 11% of lab building energy use (Labs21, 2001) and occupancy sensors have been shown to reduce up to 15% of lighting energy consumption (ASHRAE 90.1, 2010). The Program's initial intent was to install occupancy sensors in all three Pilot Labs to take advantage of these potential savings. However, our first trial in the Ham- Rek lab revealed actual savings from this approach can be highly situation-specific. The team's Energy Engineer suggests a thorough exploration of the following factors before committing to occupancy sensors as a means for energy savings in academic laboratories.

The User Experience: Preliminary trend data in all three pilot labs showed the labs were consistently turning their lights off at the end of workdays and on weekends. We therefore hypothesized that weekday daytime shutoffs would yield the greatest additional savings, based on the assumption that workers might vacate spaces during their workday and forget to turn off the lights. However, both trend data and occupant interviews revealed at least one person almost always remained in the lab during standard work hours, reducing the opportunity for automatic shutoffs during the day. Additionally, when occupancy sensors were installed in the Ham-Rek lab, researchers experienced unexpected blackouts due to sensor sensitivity issues and line-of-site obstructions caused by bulky lab equipment. Facilities electricians continually visited the site to optimize sensitivity and struggled to work around line-of-site obstructions, a repeated service that reduced the Program's return-on-investment.

Technological Advances: LED lighting technology is advancing quickly, creating an inverse relationship between first costs and fixture efficacy / efficiency. The former (cost) continues to decrease while the later (efficacy / efficiency) continues to increase, which raises the question: How much are occupancy sensors really going to save in the long term? The cost of sensor materials, labor, troubleshooting, and standard operations may not be worth the savings when the LED lights themselves are already saving a substantial amount of energy.

Individual Space Traits: At the end of the Program, the Team's Energy Engineer strongly recommended a detailed investigation into any lab space with a proposal for occupancy sensors. In some situations, labs can avoid unwanted energy consumption by ensuring the lights turn off on nights and weekends when the lab population is less diligent with end-of-day shutoffs or if a lab is frequently vacating their space for long periods during daytime hours. However, if occupants are already performing best practices, it may not be necessary to pay for the equipment and labor to realize these small savings. Additionally, occupancy sensors might be a better fit for communal lab spaces in which there is no clear space owner, or the space is frequently left empty by a variety of users coming in and out for specific or discreet processes.

BIG WINS FOR THE CIVELEK LAB: SWITCHING FROM -80 TO -70°C ON ULTRA-LOW TEMP FREEZERS



Despite occupying the oldest building out of all the Pilot Labs, Dr. Civelek's team had the most recently renovated space, smallest physical footprint, and lowest lab population. Odds were stacked against them in achieving significant savings through this program, but their willingness to adopt cutting edge sustainability practices helped them realize an overall lab energy reduction of 15.6%, the largest reduction of all three Pilot Labs. These savings were achieved after switching to -70°C ULT freezer setpoints from -80°C.

Ultra-low temperature freezers and the burden of over-cooling:

Although not peer-reviewed in its entirety, a growing body of reliable evidence supports the premise that default ULT setpoints should start at -70°C and only decrease to -80°C under special circumstances.

Freezers are mechanical systems, and mechanical systems that work harder and longer (i.e., the typical compressor-based ULT set to -80°C) will more than likely fail faster and more abruptly than a ULT set to a more moderate setpoint (CU Boulder Green Labs 2018; Faugeroux, 2016; My Green Lab, 2017b)

Hard-working freezers set to colder temperatures, on average, make more noise and generate more heat than their warmer counterparts (CU Boulder Green Labs 2018; Faugeroux, 2016; University of Copenhagen, 2018), both aspects being energetically adverse side effects in confined lab spaces.

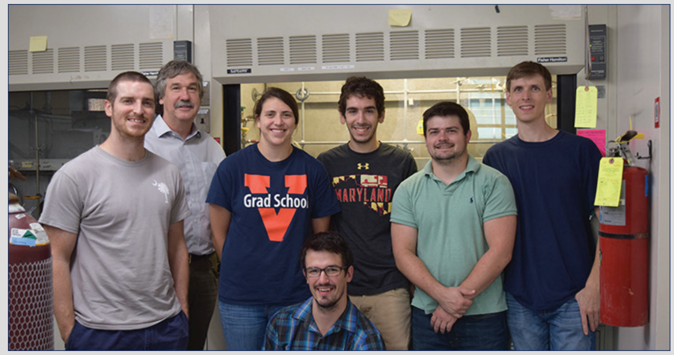
Regardless of unit age, a ten-degree change can reduce energy consumption, on average, by 37% (Paradise et al., 2016). In the case of the Civelek lab, one unit saw a 16% reduction and their second, a 40% reduction after increasing setpoints by ten degrees centigrade (Appendix A).

The Green Labs community, to date, is unaware of a science-based reason for the industry switch from -70 to -80°C which happened approximately 15 to 20 years ago. To our knowledge, lab freezer manufacturers were the first to make the change, marketing colder freezers to consumers (CU Boulder Green Labs 2018; My Green Lab, 2017b).

There is evidence that most samples and reagents do not require -80°C storage for maintaining long-term stability and viability. The University of Colorado Boulder has compiled a database of labs from their own institution and others (including Universities of California Riverside, Davis, and San Diego, Harvard, the University of Alabama Birmingham, and Virginia Tech) in which the lab lists materials they are storing at -70°C. Common sample or reagent types include nucleic acids, most proteins, bacteria and viruses (i.e. glycerol stocks, cell supernatants), cell strains, some antibodies or serum, yeast strains, and more (Beekhof et al. 2012; Burke and Henson, 1998; CU Boulder Green Labs, 2015 - 2018; Espinel-Ingroff et al., 2004; Farkas et al., 1996; Miller et al., 2008). Half of CU Boulder's ULTs are set to -70°C, and the U.S. Centers for Disease Control and Prevention made the switch on 60 ULTs in 2012 (CU Boulder Green Labs 2018; York, 2013). A follow-up in 2018 confirmed that no CDC samples or reagents appear to have been affected in any way by the switch (personal correspondence with the author).

In short, switching ULT freezers to -70 from -80°C will not only save energy, but more than likely extend the life of a freezer while reducing noise pollution and heat production. The Civelek Lab realized significant savings by making this one simple change with the click of a button.

BIG WINS FOR THE HARMAN LAB: APPLYING TIMERS TO DRYING OVENS FOR LAB GLASSWARE



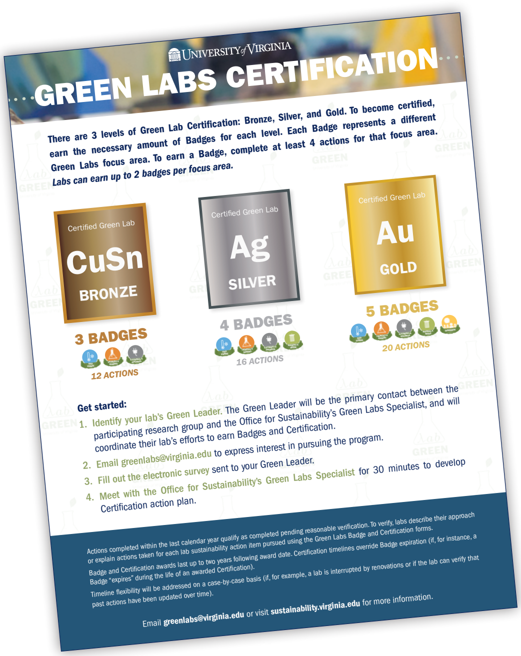
The Harman lab offered OFS a very different kind of space to work in. Home to four different drying ovens set as high as 300°C, -80°C immersion coolers, rotovap condensers, and a mass spectrometer, we found a high equipment-needs lab. While some equipment required overnight functionality (ex. rotovap condensers), we identified three drying ovens as candidates for automatic shutoff programs via outlet timers.

A variety of options were tested, including timers with Wi-Fi connectivity, Bluetooth technology, and digital multi-schedule programming capabilities. In the end, a simple diurnal analog timer was the most effective option, as cellphone signals were unreliable in the building, Wi-Fi connectivity to UVA's wireless network was not possible, and digital timers were complicated to program reliably. Lab members would also perform experiments on the weekends, eliminating the need for the more expensive digital timers that provide day-to-day program variation capabilities. Analog timers are an inexpensive way to ensure reliable nighttime shutoffs of lab equipment, and the Harman lab drying ovens will save up to 2,000 kWh / year, almost 20% of the annual average for electricity use in American homes. Overall, the lab reduced their energy consumption by 6%.

CONCLUSIONS AND FUTURE DIRECTIONS

GREEN LABS CERTIFICATION

Working with our own researchers allowed for the exchange of institution-specific information, expertise, resources, and services between OFS and partner labs. These collaborations were instrumental in the creation of UVA's new Green Labs Certification Program, designed to be a robust but flexible and achievable engagement tool for all UVA labs. Many other institutions have their own sustainability certification programs, and national standards have been published, such as My Green Lab's national certification form (My Green Lab, 2017c). The Green Lab Specialist suggests that both local and national level certifications have important but unique roles to play in Green Labs programming. Researchers can benefit from locally focused programs tailored to the community but will have additional opportunities to gain recognition on a national scale. While national programs are broader and perhaps less resource-intensive, they are an important means for benchmarking alongside other institutions and gathering data on the progress of Green Labs progress. OFS intends to pursue My Green Lab's national certification in addition to our own as a means for comparing our research environment to others.



INTRODUCING SMART LABS

Lab buildings are not designed like other buildings—they are equipped with complex ventilation and exhaust systems intended to protect scientists from airborne contaminants that might be introduced during experiments (ASHRAE, 2015). Mechanical systems in lab buildings are often constantly in use, supplying laboratories with large volumes of fresh air, based on the assumption that higher rates of ventilation result in fewer airborne contaminants and safer labs. This high airflow rate comes at a tremendous cost to the environment and institutional budgets with an average lab building consuming up to four times more energy than commercial buildings (U.S. Department of Energy). Additionally, a "one-size-fits-all" approach to lab ventilation does not address the diversity of lab arrangements, risk levels, exhaust points, and many other factors contributing to airborne contaminant dispersal. To further reduce risk and ventilation demand, the development of a UVA Smart Labs Program is underway. Named for and modeled after the University of California Irvine's intensive lab building upgrade program (Brase, 2016) and the Department of Energy's Smart Labs Accelerator, UVA Smart Labs will incorporate successful researcher engagement tools adopted in the 2018 Pilot Program while simultaneously addressing safety and energy use deficiencies in our lab buildings. To achieve this, Smart Labs will engage all stakeholders including Environmental Health and Safety (EH&S), lab researchers, Facilities Management maintenance personnel, and the Building and Operations team within the Office for Sustainability (Delta Force team). Implementation of such a program will not only improve lab safety but predicts to reduce lab energy consumption as much as 40%, resulting in $5.5 million in annual savings. UVA Smart Labs will pursue a holistic approach to creating safe and sustainable laboratories by advancing the built environment to better serve our scientific community and empowering researchers to adopt best practices in their daily operations. Together we can shift the culture of science from one that was maximized, to one that is right-sized for smart, safe, and sustainable discovery.

ACKNOWLEDGEMENTS

The authors would like to thank our three Pilot Labs for their willingness to champion sustainability through this experimental process. By allowing the Office for Sustainability into their space, we gained invaluable insight that has and will continue to shape sustainable lab initiatives at UVA. Many thanks to the Green Labs Working Group, the OFS Outreach and Engagement team, and the OFS Delta Force team for their many contributions to the progress and successes of the Pilot Program. A special thanks to Samantha Campbell for design support, to Andrew Pettit for advising on data visualization, and to the many Facilities maintenance crews who performed renovations in Pilot Labs that enabled participants to realize a variety of sustainable benefits and improved research environments.

REFERENCES

ANSI/ASHRAE/IES Standard 90.1-2010, 2012. "Energy standard for buildings except low-rise residential buildings", Atlanta, Section 9.

ASHRAE (2015), "ASHRAE applications handbook – HVAC applications", Atlanta, Section 16.

Beekhof, P.K., Gorshunska, M., Jansen, E.H.J.M. (2012), "Long term stability of paraoxonase-1 and high-density lipoprotein in human serum", *Lipids in Health and Disease*, 11, 53-55, (accessed 5 February 2019).

Bell, G.C. (2012), "Fume hood sash stickers increases laboratory safety and efficiency at minimal cost: success at two university of California campuses", U.*S. Department of Energy Federal Energy Management Program*, (accessed 7 February 2019).

Bell, G.C., Mills, E., Sartor, D., Avery, D., Siminovich, M., Piette, M.A. (2003), "A design guide for energy-efficient research laboratories", *Lawrence Berkeley National Laboratory, Center for Building Science, Applications Team*, publication number 777, (accessed 7 February 2019).

Brase, W. (2016), "Smart labs initiative", *The Regents of the University of California*, (accessed 7 February 2019).

Burke, H.B. and Henson, D.E. (1998), "Specimen banks for cancer prognostic factor research", *Archives of Pathology and Laboratory Medicine*, 122, 871-874, (accessed 5 February 2019).

CU Green Labs Program (2018), "-70°C Efforts", *University of Colorado Boulder Environmental Center*, (accessed 8 February 2019).

CU Green Labs Program and contributors (2015 - 2018), "Biological samples stored long term at -70°C or warmer", *University of Colorado Boulder Environmental Center*, (accessed 8 February 2019).

Espinel-Ingroff, A., Montero, D., Martin-Mazuelos, E. (2004), "Long-term preservation of fungal isolates in commercially prepared cryogenic microbank vials", *Journal of Clinical Microbiology*, 42, 1257-1259, (accessed 5 February 2019).

Farkas, D.H., Kaul, K.L., Wiedbrauk, D.L., Kiechle, F.L. (1996), "Specimen collection and storage for diagnostic molecular pathology investigation", *Archives of Pathology and Laboratory Medicine*, 120, 591-596, (accessed 5 February 2019).

Faugeroux, D. (2016), "Ultra-low temperature freezer performance and energy use tests: Stirling Ultracold SU78UE, Eppendorf Cryocube 570h, Thermo Fisher TSX600", *University of California Riverside Office of the President and Office of Sustainability*.

Gilly, Q. (2016), "Validating cost and energy savings from Harvard's Shut the Sash Program. Tackling energy use in labs", *Harvard University Office for Sustainability*, (accessed 24 January 2019).

Greever, C., Nahreini, T., Ramirez-Aguilar, K. (2018), "A case study of the Biochemistry Cell Culture Facility at the University of Colorado Boulder: avoided costs and other benefits resulting from shared equipment in collaborative research space", *University of Colorado, Boulder Environmental Center and Facilities Management*, (accessed at 24 January 2019).

Hafer, M. (2015), "Inventorying Plug Load Equipment and Assessing Plug Load Reduction Solutions on a University Campus", *Stanford University Department of Sustainability and Energy Management*, (accessed 24 January 2019).

Laboratories for the 21st Century (Labs21): Case Studies (2001), "The Louis Stokes Laboratories, Building 50, National Institutes of Health, Bethesda Maryland", (accessed 7 February 2019).

Lawhon, C. (2012), "UCI's new and retrofitted Smart Labs employ occupancy and air-quality sensors to cut energy use by 50 percent," *UCI News,* 13 February 2012, (accessed 7 February 2019).

Michetti, A. (2016), "Reducing Laboratory Energy Use Through Data-Driven Behavior Change Campaigns", *Harvard Office for Sustainability*, (accessed 7 February 2019).

Miller, L., Anekella, B., Manak, M., Garrett, P. (2008), "Twenty year stability study of HIV, HBV, and HCV antibodies, antigen and nucleic acids in plasma", *American Association of Blood Banks (aabb) annual meeting in Montreal, Canada, 2008*, (accessed 5 February 2019).

My Green Lab (2017), "Programs" page, (accessed 7 February 2019).

My Green Lab (b) (2017), "-70 is the new -80" page, (accessed 5 February 2019).

My Green Lab (c) (2017), "Certification" page, (accessed 5 February 2019).

Paradise, A., Livchak, D., Ruan, E., Farmer, A. (2016), "Ultra-low temperature freezers: opening the door to energy savings in laboratories", *Pacific Gas and Electric Company and The Center for Energy Efficient Laboratories*, (accessed 8 February 2019).

United States Department of Energy, Better Buildings, "Smart labs accelerator fact sheet", (accessed 5 February 2019).

University of Copenhagen (2018), "Plug load test for ULT Freezers: 20-22% lower energy consumption at -70°C compared to -80°C", (accessed 24 January 2019).

University of Virginia Sustainability Plan (2016), "Steward", page 18, (accessed 17 January 2019)

York, L. (2013), "Centers for Disease Control and Prevention Lab Freezer Challenge", presented at the 2013 annual conference for the International Institute for Sustainable Laboratories, (accessed 11 January 2019).

Appendix A: Compressor cycle trends for two ultra-low temperature freezers in Dr. Civelek's lab before and after warming to -70°C from -80°C. The newer Thermo Fisher TSU500 (upper two quadrants) saw a 16% decrease in energy consumption and five fewer compressor cycles per hour, while the older Thermo Fisher Forma 900 (lower two quadrants) saw a 40% decrease in energy consumption and seven fewer compressor cycles per hour. The elimination of short cycles on the Forma 900 illustrates reduced stress on a freezer compressor and improved temperature stability after application of moderate freezer setpoints.