

**Caltech Green Labs Report**

Developed in 2024

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**Executive Summary**

The Green Labs program is currently fully funded by BBE, with an annual budget of about $10,000. This group is entirely volunteer-based. Despite this, in it’s first year the Green Labs group has accomplished much. At the time of writing, they developed several pilot programs, redirecting over [1,700 pounds of food waste, and 1,000 pounds of lab plastic waste](https://greenlabs.caltech.edu/green-labs-pilot-programs) that would have otherwise not been diverted from landfill. This group also expanded the [Green Labs Certification program](https://greenlabs.caltech.edu/green-labs-certification); in January of 2023 there were only 2 labs Certified, but now the number of Certified labs includes 20 labs. This group has run several successful campaigns, including a [Lab Clean Up Event](https://greenlabs.caltech.edu/lab-spring-clean-event), where they developed resources and how-tos to encourage labs to compete to clean up their lab spaces, and put on the first [Annual Lightning Talks Event](https://greenlabs.caltech.edu/green-labs-events), inviting speakers from across campus to present on sustainable initiatives, in addition to monthly meetings and [social media](https://www.instagram.com/caltechgreenlabs/) presence. Furthermore, an [Action Plan](https://greenlabs.caltech.edu/green-labs-action-plan), [Green Labs Guide](https://greenlabs.caltech.edu/green-labs-guide) (with helpful tips and tricks for making labs sustainable), [Sustainable Restaurant Guide](https://greenlabs.caltech.edu/documents/26726/Sustainable_Restaurants_Resources_V3.pdf) and [Sustainable Breakfast/Coffee/Dessert Guide](https://greenlabs.caltech.edu/documents/27161/Sustainable_Coffee_Breakfast_and_Dessert_Resources.pdf), and other [resources](https://greenlabs.caltech.edu/lab-spring-clean-event) such as recycling signage and [sustainable products lists](https://docs.google.com/spreadsheets/d/1Ojc3-lN9pq1RcXRig-Dq0q1RuPxsDnv8BRYYtYVdNHM/edit?usp=sharing) were developed to promote sustainable best practices. This group collaborated with several organizations including (but not limited to) the Women in BBE group, the Graduate Student Council Sustainability Committee, and Plant-Based Universities group, USA Scientific, Genesee, Eppendorf, CIT Lab Managers Group, and presented at the International Institute for Sustainable Laboratories (I2SL) in late 2023.

These accomplishments were all done with a group of very dedicated volunteers. Now, imagine what could be accomplished with a full-time dedicated employee. There is a huge opportunity for a full-time Green Labs Coordinator to continue the work of this group and implement money-, energy-, and water-savings measures that far exceed what is possible with a volunteer group. This position would provide guidance to enhance safety and environmental compliance, aid facilities, EHS, Sustainability, and other departments, including educational aspects furthering training on sustainable best practices. Furthermore, due to the hard work of numerous volunteers, there are already many programs in the pilot stages it would be easy to expand and build upon. As many of the programs developed over the past year are thoughtfully put together and implemented, this group has developed a lot of trust with labs, which can be built upon to make even more change occur on campus.

A robust Green Labs program has the potential to collaborate with other university Green Labs programs, as well as work with and inspire other institutions to develop their own Green Labs programs. Of twenty nine peer institutions, twenty three have Green Labs programs. Caltech’s Green Labs program has an opportunity to stand out among peer institutions and aspirational institutions. This program will educate future scientists in sustainable laboratory practices, enhance the safety of researchers and personnel, reduce energy, water, and landfill/hazardous waste costs, and cut operational costs for this campus. Best practices are utilized in industry, so adoption of these practices will train our students and instill a strong foundation in globally recognized sustainability measures.

This report presents the potential of Green Labs programs, utilizing resources from peer and aspirational institutions to determine (where appropriate) expected cost savings estimates for each initiative at Caltech. Topics explored include Energy and Water Reduction Initiatives, Waste Reduction and Recycling Initiatives, Purchasing and Packaging Reduction, and Green Chemistry and Safety Initiatives. **The initiatives described in this report represent an annual potential savings of at least $303,167 in energy, water, and waste disposal costs (see Table 1 for more detailed breakdown of cost savings).** To conclude, incentive programs are explained and explored, and administration and financing recommendations are provided.

This report was developed based on a similar [report from the University of Georgia](https://drive.google.com/file/d/1pLFPBdtLQ7IYHRB1vuFdgYYDJk-RE-A5/view?usp=sharing).

**Introduction**

Green Labs programs are designed to promote and support world-class science by engaging researchers in best practices to enhance safety, conserve resources, and reduce waste. Most programs have aspects of engagement, education, and recycling or other initiatives to further these goals. As such, a full-time Green Labs Coordinator would have roles in numerous areas including (but not limited to): promoting zero-waste initiatives, if Caltech chooses to adopt such initiatives; working with the Graduate Student Council Sustainability Committee on their ambitious goals; providing internship opportunities for students; conducting lab clean up initiatives and space allocation surveys; running the Glassware, Equipment, and Chemical Exchange program; participating in procurement negotiations; work with EHS and biosafety to make labs not only safer but also more sustainable (Green Labs Representative roles could even be incorporated into already-existing Safety Officer roles); working with facilities to reduce service requests, conduct inventories, and increase oversight; working on long-term projects such as chilling up ultra-low temperature freezers, fume hood and freezer inventories and upgrades, and autoclave share programs.

Proposed Energy and Water Reduction Initiatives, including Shut the Sash initiatives, have the potential to save Caltech upwards of at least $193,812. Refrigeration programs, such as Chilling Up Ultra Low Temperature Freezers, have the potential to save Caltech a minimum of $17,780. Lastly, Autoclave programs, including Solenoid Education and Replacement Program, have the potential to save Caltech [95% of wasted water and 70% energy](https://www.priorclave.com/en-us/jacketed-or-non-jacketed-autoclave/) from under- or mis-utilized autoclaves as compared to doing nothing, though exact estimates are difficult to guess given Caltech currently has no estimated number of autoclaves on campus. These initial estimates indicate an annual savings of $211,600.

Waste Reduction and Recycling Initiatives include programs such as Laboratory Plastics Recycling or Reuse, have the potential to save Caltech at minimum $82,325 in waste disposal fees. Laboratory Glassware, Equipment, and Chemical Share Program, and Composting (comprised of Composting Animal Cage Bedding and Composting in Laboratory Kitchen Areas) have a minimum savings of $5,610 though these values are hard to estimate as they are dependent on many factors, though one goal of these programs could be to reduce hazardous waste costs by 15% (the amount it has risen since 2015). These initiatives together have the potential to save Caltech upwards of $87,935.

Purchasing and Packaging Reduction, along with Green Chemistry and Safety Initiatives (including Chemical Substitution and Chemical Sharing programs), are sure to provide monetary savings for labs at Caltech. However, it is difficult to estimate the annual savings accurately, though we may set a goal here of 10% savings (which is what other groups set a minimum goal of).

The initiatives described in this report represent an annual savings of at least $303,167 in energy, water, and waste disposal costs (Table 1). To conclude, incentive programs are explained and explored, and administration and financing recommendations are provided, along with estimated return on investment timelines.

**Table 1.** Breakdown of each initiative and the presumptive minimum estimate of savings, if possible to estimate.

|  |  |  |
| --- | --- | --- |
| Initiative | Presumptive Cost Savings Estimate | Notes or Caveats |
| Fume Hood Shut the Sash OR Motion and Sash Height Sensors | $149,250 | Assuming $250 savings per 597 unalarmed fume hoods |
| Fume Hood Hibernation | $21,390 | Assuming we can shut off 3% of the 713 fume hoods on campus and those fume hoods have “efficient” energy requirements |
| Fume Hood Reduced Face Velocity | $23,172.50 | Assuming we can reduce the face velocity of 10% of 713 fume hoods on campus, saving $324 each on average |
| Chilling Up Ultra Low Temperature Freezers | $17,788.20 | Assuming a 30% savings on changing from -70˚C to -80˚C on inefficient models using 19 kWh per day (which make up 30%-40% of 150 ULTs on campus). Assuming only half can be chilled up. |
| Refrigeration Repair | Cannot estimate |  |
| Equipment Trade-Ins | Cannot estimate |  |
| Cold Room Upgrade | Cannot estimate |  |
| Autoclave Solenoid Replacement | $3,631.50 | Assuming only one autoclave as there are no estimates of numbers of autoclaves on campus. Note, each solenoid costs $1-10k depending on model to replace, but this will save a minimum of $3,631 per autoclave in water savings |
| Lab Plastics Recycling | $9,000 | Assuming we can divert 1% of landfilled lab waste (initial investment of $500 but few continuing costs) |
| Pipette TipCycle Program | $73,325 | $73,325 savings per year for one lab (using 36,000 tips a year). Initial investment of $121K, but this automated machine can support 20-30 labs so will pay for itself within one year if even two labs utilize it. |
| Glassware/Equipment/Chemical Share Program | Cannot estimate | Cannot estimate, but set a goal of 10% reduction in purchasing costs |
| Animal Bedding Composting | $5,165 | If there is 50% diversion of this waste. Currently we dispose of 18,720 kg of bedding a year. |
| Food Waste Composting | $445 | This is the current waste diversion of over 1000 lbs of waste, with only 3 Lomi composters. If the program were to grow this number will be significantly higher. |
| Sustainable Events | Cannot estimate | Cannot estimate |
| Purchasing | Cannot estimate | Cannot estimate, but set a goal of 10% reduction in costs |
| Green Chemistry | Cannot estimate | Cannot estimate, but set a goal of 10% reduction of hazardous waste disposal costs |
| Chemical Substitution | Cannot estimate | Cannot estimate, but set a goal of 10% reduction of hazardous waste disposal costs and/or purchasing costs |
|  |  |  |
| TOTAL | **$303,167.2** |  |

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**Peer Institutions and Aspirational Green Labs Programs**

**Top National Programs**

Green Labs programs are becoming more common among universities at all levels. At the time of writing, of twenty nine peer institutions, twenty three have current Green Labs programs (please see Appendix for detailed descriptions of their Green Labs programs), with eleven supporting at least one dedicated full-time Green Labs employee (Appendix Table 1). Four of Caltech’s peer universities have programs that stand out as having leading Green Labs programs: University of Georgia (UGA), University of California Davis (UC Davis), University of Colorado Boulder (CU Boulder), and Massachusetts Institute of Technology (MIT).

[UGA Green Labs Program](https://greenlab.uga.edu/) includes initiatives focusing on energy saving, procurement, waste diversion, and water savings. This group is also focused on making complete and accurate Life Cycle Analyses of various products, including gloves (for which they have spent over four years researching the purchase of ethically-sourced gloves for their laboratories.)

[UC Davis Green Labs Program](https://sustainability.ucdavis.edu/green-workplace) has developed an exemplary Green Labs Certification program wherein labs are awarded two-year Bronze, Silver, or Gold Certifications depending on how many points are achieved in various categories (ranging from community engagement, energy, fieldwork, green chemistry, travel, waste, and water initiatives). They have a minimum expectation that Lab Champions spend at least four hours per month working on initiatives for the Green Labs program. Furthermore, they have developed resources not only for Green Labs, but also for Green Workplaces (including Green Home Office and Green Study Space).

[CU Boulder Green Labs Program](https://www.colorado.edu/ecenter/programs/cu-green-labs-program) is one of the oldest and best-run programs in the US. This group has developed resources for labs in various categories including energy, water, and waste solvent re-use, equipment sharing and efficient space use, funding connections, social justice, and fervently support the International Freezer Challenge, as they are one of the original competitor universities and have one of the longest and most established programs in the US. Their program also provides resources for the Green Labs Community to establish their own programs, and to answer some commonly-asked questions. This program awards Green Lab Awards based on nominations from the community.

[MIT Green Labs Program](https://ehs.mit.edu/sustainable-labs/) has focused on several areas of sustainability including recycling and waste reduction, pollution prevention, chemical inventories, safe and sustainable labs, cold storage, and green chemistry. In fact, their team is so dedicated to green chemistry and chemical substitution they developed the [Green Alternatives Wizard](https://ehs.mit.edu/green-chemistry/), which is a database allowing comparison of safer or less energy intensive chemical alternatives or processes.

**Peer Institutions**

Of the twenty nine peer institutions listed, twenty three have Green Labs programs (each of their programs are briefly described in the Appendix). Furthermore, data was collected for each of the twenty-nine universities including if they have a Green Labs program, if they include a dedicated full-time employee, what their R&D budget was for 2023, what their 2023 endowment is, and an estimate of how many research labs each university houses (Table 2, or Appendix Table 1).

Caltech has an opportunity to stand out and mentor peer universities that do not have, or are currently developing, Green Labs programs, giving us an opportunity to lead amongst our peers. Six universities of the twenty nine peer universities investigated do not have Green Labs programs. This includes: [Carnegie Mellon University](https://guides.library.cmu.edu/c.php?g=935663&p=7236721) (though this group has put together resources for Chemical Awareness and Sustainability and other Green Labs programs); [Georgia Institute of Technology](https://sustain.gatech.edu/) (supports living campus initiatives, zero waste commitments, and [supports](https://www.ehs.gatech.edu/) sustainable shipping, radiation safety, lab and chemical safety, hazardous waste disposal, general safety, and fire safety initiatives); [Purdue University](https://www.purdue.edu/physicalfacilities/units/cpas/sustainability/index.php) (which is focused on creating sustainable buildings, farmers markets, events such as [Green Week](https://www.purdue.edu/physicalfacilities/units/cpas/sustainability/involved/green-week.html), and recycling programs); the [University of Illinois at Urbana Champaign](https://sustainability.illinois.edu/green-certifications/certified-green-chapter-program/) (which is participating in the [Campus as a Living Laboratory program](https://sustainability.illinois.edu/research/campus-as-a-living-laboratory-research-campus-sustainability-working-together/) and has initiatives such as Certified Green Events, Certified Green Office, and Certified Green Chapter); the [University of Southern California](https://dornsife.usc.edu/news/stories/chemists-create-greener-research-labs/) (does not have a Green Labs program, though several labs have implemented sustainable research techniques including introducing the 12 principles of green chemistry); and the [University of California San Francisco](https://campuslifeserviceshome.ucsf.edu/sustainability/certifications) (their sustainability group has [certification programs](https://campuslifeserviceshome.ucsf.edu/sustainability/certifications) for Offices, Labs, Clinic/Unit, Event Planners, and Catering. This group also has commitments for decarbonization, and supports ULT freezer rebates, discounts on sustainable products, Bunsen burner switch outs, equipment reuse programs, campus waste divestment, water efficiency, and transportation initiatives).

**Aspirational Institutions**

Some examples of aspirational peer university Green Labs programs are described below. Further information for the twenty three other peer/aspirational institutions that have Green Labs programs can be found in the Appendix.

[Texas A&M University – College Station](https://semc.tamu.edu/greens-labs-certification-program/index.html) has developed a Green Lab program that labs can apply to online and are awarded points in fifty categories (including Styrofoam and glove recycling, chemical and equipment and chemical sharing, freezer maintenance, room temperature DNA storage, and mercury thermometer exchange, to name a few), alongside a lab walkthrough with EHS to confirm a checklist of items and initiatives. This Certification needs to be resubmitted every two years to maintain or update Certification level.

[University of Alabama at Birmingham](https://www.uab.edu/sustainability/greenlab) Green Labs program focuses on reduction of energy, water, material goods, and hazardous chemicals. They have a Green Labs Certification program that assesses labs alongside a partnership with EHS, and provides generalized guidelines that allow for individual labs to develop additional practices specific for their labs. Each lab selects a Green Labs Representative that takes a survey and encourages at least half of their lab to also complete the survey, then this assessment is reviewed and changes are suggested. Once changes are implemented, labs are granted Certification at five levels depending on how successfully suggested changes were implemented. Further resources include a [Green Labs Primer](https://www.uab.edu/sustainability/images/Documents/green-labs-onboarding.pdf) to introduce new researchers to Green Labs practices, [Lab Recycling and Reuse Program](https://www.uab.edu/sustainability/greenlab/lab-recycle), and [ULT Freezer Reservation program](https://www.uab.edu/sustainability/greenlab/reserve-a-ult-freezer).

[University of British Columbia](https://sustain.ubc.ca/green-labs) Green Labs program supports researchers to reduce energy and water use, improve lab recycling, access funding, implement sustainable solutions, and facilitate community conversations about best practices. This program also includes resources for Chill Up Challenge, Shut the Sash program, Waterless Condenser rental program, freezer rebate program, international freezer challenge, and free outlet timers. They certify labs through the (paid-for) My Green Labs Certification program, and offer a [Lab Sustainability Course](https://sustain.ubc.ca/programs/green-labs-program/lab-sustainability-course) and [Sustainability Coordinator Programs](https://sustain.ubc.ca/programs/sustainability-coordinator-program) to better engage and train interested researchers. Though this university is in Canada, we felt inclusion of this program was necessary.

[University of California Irvine](https://sustainability.uci.edu/green-lab/) Green Labs program is one of the first formal programs ever developed. This program has resources ranging from a [Welcome Guide and Checklist](https://sustainability.uci.edu/wp-content/uploads/2022/03/Welcome-Guide-UPDATED.pdf), to downloadable signs and labels, guidelines for sustainable remote research, energy efficiency, water conservation, waste reduction, green chemistry, and procurement, alongside their (paid-for) My Green Labs Certification program. UC Irvine also hosts [sustainability staff training](https://sustainability.uci.edu/education/staff-professional-development-and-training/). Furthermore, UC Irvine is the homebase for many educational tools such as the [Smart Labs Program](https://www.ehs.uci.edu/energy/index.php), encouraging labs to build better and more sustainable laboratories, and assess needs for things such as energy consumption empirically.

[University of California Los Angeles](https://www.sustain.ucla.edu/green-labs/) Green Labs program offers a comprehensive Green Labs Certification program that includes an assessment of current practices that produces recommendations and educational tools on how each individual lab can reduce environmental impact. After three months of implementing the recommendations and tools, a reassessment is conducted and certification granted (depending on progress). Their program also offers resources on freezer maintenance and updating, waste disposal, [green event certification](https://www.sustain.ucla.edu/green-events), and they provide grant money for sustainable projects with their [Green Initiative Fund](https://www.tgif.ucla.edu/), as well as having a [zero waste commitment](https://www.sustain.ucla.edu/zero-waste/) and a [green buildings](https://www.sustain.ucla.edu/green-buildings/) commitment, among others.

**Table 2.** List of peer aspirational Institutions. Links are provided for institutions’ Green Labs program websites or other applicable websites. \* indicates a publicly funded university. If peer institutions have a Green Labs program and a dedicated full-time employee are indicated. R&D funding, endowment, and estimated numbers of research labs are shown.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Institution (with link to Green Labs or Sustainability programs); \* indicates publicly funded university | Green Labs Program (Y/N) | Dedicated Green Labs Full-Time Employee(s) (Y/N, number of employees if available) | [Institutional R&D funding per year](https://ncses.nsf.gov/surveys/higher-education-research-development/2022) (2023) | Endowment | Estimated number of research labs (estimated number of faculty, graduate students, postdocs, and research staff) (numbers of those researchers in labs if available) (PC=personal communication) |
| [California Institute of Technology](https://greenlabs.caltech.edu/) | Y | N | $478,142 | $3.63 B | 300+ (1,200+ faculty, 650 postdocs, 1,400 graduate students500+ research staff) |
| [Massachusetts Institute of Technology](https://ehs.mit.edu/sustainable-labs/) | Y | N (within EHS?) | $989,166 | $23.5 B | 200+ (1,089 faculty, 7,201 graduate, 1,536 postdocs, and 4,275 research staff) |
| [Texas A&M University – College Station](https://semc.tamu.edu/greens-labs-certification-program/index.html) \* | Y | N (committee) | $1,152,666 | $19.2 B | 500+ (4,100+ faculty, 16,762 graduate, 3,845 research staff) |
| [University of Alabama at Birmingham](https://www.uab.edu/sustainability/greenlab)\* | Y | Y(1.5 and 7.5 student employees) | $713,480 | $1 B | 600 (2,146 faculty, 8,851 graduate, 300 postdocs, 1,000+ research staff) (3300 graduate and staff in labs)(PC) |
| [University of British Columbia](https://sustain.ubc.ca/green-labs) \* | Y | Y |  | $2.8 B (CD) | 300+ (3,800+ faculty, 10,000+ graduate students, 1,000 postdocs, 5,696 research staff) |
| [University of California Davis](https://sustainability.ucdavis.edu/green-workplace) \* | Y | N (one member of the sustainability team is involved in GL efforts) | $883,807 | $2.25 B | 200+ (2,500+ faculty, 7,000 graduate, [745 postdocs](https://ucnet.universityofcalifornia.edu/resources/employment-policies-contracts/bargaining-units/postdoctoral-scholars/about/), and 1200+ research staff) |
| [University of California Irvine](https://sustainability.uci.edu/green-lab/) \* | Y | N (GL working group) | $534,947 | $1.3 B | 100+ (1,553 faculty, 8,019 graduate, 451 postdocs, 6,890+ research staff) |
| [University of California Los Angeles](https://www.sustain.ucla.edu/green-labs/) \* | Y | Y (2? Grant coordinator and zero waste manager) | $1,536,197 | $7.7 B | 800+ (2,960 faculty, 14,007 graduate, 989 postdocs, and 7,941 research staff) |
| [University of Colorado Boulder](https://www.colorado.edu/ecenter/programs/cu-green-labs-program) \* | Y | Y (2 plus 12 student employees) | $611,380 | $2.1 B | 400+ (4,800 faculty (2,000 research faculty), 6,446 graduate, and 900 research staff) (2,000 graduate researchers and staff in labs)(PC) |
| [University of Georgia](https://greenlab.uga.edu/)\* | Y | Y (1 and 2 student employees) | $545,631 | $1.4 B | 250+ (3,000+ faculty, 9,041 graduate, 1,000+ research staff) |

**Recommended Green Labs Initiatives**

The Caltech Green Labs program will include three main aspects: engagement, education, and policy change.

The first aspect of the Green Labs program will involve engaging with labs. One way of engagement will be through the opt-in Green Labs Certification program (outlined below) to change behaviours, challenge labs to adopt sustainable best practices, and set Certified labs above and beyond peer labs. The Green Labs program also will promote participation in sustainable programming such as the Annual Lightning Talks Event, Spring Clean Event, International Freezer Challenge, and Certified Exclusive Events. Monthly meetings will allow labs to interact, learn, ask questions, and design future events and programming alongside the Coordinator. Posters of ongoing programs and events will be posted throughout relevant buildings. A yearly Action Plan and Green Labs Guide will be published to keep us accountable to our community and keep labs up-to-date on best practice suggestions. Resources, such as fact sheets, slides, and information sessions will be available on our website. Funding will be provided for small sustainable pilot projects; applications will be reviewed by a committee before approval. We also hope to offer one-on-one assessments for labs that request it, and collaborations with EHS during safety inspections to ensure safety compliance and sustainability goals are being met.

Furthermore, Green Labs hopes to educate the community about sustainable best practices. Green Labs hopes to train individual students during internships. This will not only allow us to engage with a small group of students directly, it will also allow us to do Green Labs projects that would otherwise be outside the scope of a single person or group of volunteers. Furthering their studies is paramount, so each student will be able to run or research their own independent projects alongside working on larger Green Labs projects. Additionally, Green Labs hopes to be integrated into lab safety trainings that each researcher is required to take, ethics training, orientation events for new students, staff, and faculty, and help develop undergraduate and graduate coursework (including for lab-intensive courses), and other training programs (such as this [Green Labs Certificates](https://sustain.ubc.ca/lab-sustainability-course) program from the University of British Columbia, that includes individually-driven coursework).

The third aspect of the Green Labs program will include policy changes across the university, in alignment with the goals of the Sustainability Council, and in conjunction with (but not limited to) the Sustainability Office, EHS, OLAR/IACUC, Purchasing, and Facilities. These policy changes will build upon existing and expected lab safety and environmental compliance mandates, and will work to ensure ease of adoption of sustainable practices for labs, as well as benefit the campus as a whole by certifying sustainable goals are reachable and reasonable.

The proposed initiatives are divided into topic areas including Green Labs Certification, Energy and Water Initiatives, Waste Reduction and Recycling Initiatives, Purchasing / Packaging Reduction, and Green Chemistry Initiatives.

**Green Labs Certification**

Green Labs Certification programs remain a common method for interacting with labs, and providing feedback on areas where labs are succeeding in their sustainable efforts and areas where there is room for improvement. Currently, the [Caltech Green Labs Certification](https://greenlabs.caltech.edu/green-labs-certification) program is comprised of a [self-assessment form](https://greenlabs.caltech.edu/documents/22943/Green_Lab_Certification_aWglwUK1.xlsx) that labs complete and collect points on various topics (including commitment, administrative actions, education of lab, energy/refrigeration, materials, purchasing, and water), then submit to the Sustainablity office. This office scores the submissions, and works with labs to post their Certification plaque. The Green Labs program has updated this form, and in the first year after taking over advertisement of the program have increased the number of Certified labs from 2 to 20. The assessment form was built upon existing and expected lab safety and environmental compliance mandates, and aims to further improve both sustainability and safety compliance.

In future years, we hope to re-engage labs that have gotten Certified, to maintain their commitments and also check in to see if there are additional resources we can provide to aid in even more sustainable actions being taken by labs (we hope to adopt a similar model as that used by UC Davis, where Certification needs to be resubmitted every two years). This reengagement program will hopefully be accompanied by a yearly survey, and a sticker reward system that is applied to Certification plaques indicating successful sustainable campaigns or initiatives undertaken by labs. Another aspect we hope to augment the current program with is to require that labs have no deficiencies on their annual lab safety inspections, and/or that they resolve any minor deficiencies found within a two week period (thus furthering EHS goals alongside lab sustainability goals).

**Energy and Water Initiatives**

The 2024 Strategic Plan outlined by the Sustainability Council calls for an X reduction in energy use and an X reduction in water consumption by 2030. Laboratory buildings use two to three times more energy per square foot than office buildings, mainly due to large requirements for refrigeration/temperature control and ventilation. Furthermore, autoclaves and other such equipment use large amounts of potable water (and if there are issues with the machines, have the potential to waste significant amounts of water if issues are not noticed or corrected quickly). **The initiatives described in this section have the potential to save (at minimum) between $215,232 annually in energy and water costs.**

Fume Hoods

Data from Caltech facilities indicates that Caltech currently has 713 (+/-20) fume hoods on campus (these numbers are estimated as a recent survey has not been conducted and facilities is not sure if some hoods are currently operational). However, only 116 (16%) have smart technology or are alarmed. Smart technology encourages users to close fume hoods promptly after use, reducing airflow and energy requirements of the system, either through self-closing technology or through alarms that go off if the fume hood is left unattended and open for too long. Presuming 100% compliance for the 116 fume hoods with alarms or smart technology, there are 597 fume hoods that have the potential to benefit from a concerted effort to encourage users to shut the sash. Specifically, there are several buildings that have 30+ unalarmed fume hoods, including Beckman, Broad, Church, Mudd, Noyes, Schlinger, and Spalding (Schlinger alone has 104).

Typically, a fume hood removes around [825 cubic feet](https://www.google.ca/url?sa=t&source=web&rct=j&opi=89978449&url=http://web.mit.edu/~slanou/www/shared_documents/The%2520use%2520of%2520feedback%2520in%2520lab%2520energy%2520conservation.pdf&ved=2ahUKEwj_3relxs6FAxWgIDQIHZwfDgk4FBAWegQICBAB&usg=AOvVaw10grXLxUbAGwHDJWYdJJSN) of air per minute (CFM) (value can vary depending on risk of exposures, but generally ranges from between [4 and 10 air changes per hour](https://tsi.com/getmedia/ed63b48a-7f5a-4981-911e-7f33694809bc/LC-125_Lab-Guidelines-and-Standards_RevC_US), or between [400 CFM and 1800 CFM](https://www.google.ca/url?sa=t&source=web&rct=j&opi=89978449&url=https://sustain.wwu.edu/files/2021-08/2010Spring_Hood-Fan-Energy-Conservation-Report.pdf&ved=2ahUKEwj_3relxs6FAxWgIDQIHZwfDgk4FBAWegQICxAB&usg=AOvVaw30533-36u7DGJhQvPrchyB)). This air must be conditioned, pulled into the building, filtered, and removed from the building. The average cost per fume hood per year in the United States is [$6000](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.nwf.org/~/media/Campus-Ecology/Files/Case-Studies/Harvard-Shut-the-Sash-Final.ashx&ved=2ahUKEwifztqdjs2FAxVqJEQIHUEGCGAQFnoECBkQAQ&usg=AOvVaw2UaHt0X92O9zr72E2p9DAK) and [$8260](https://pupnmag.com/article/the-cost-of-laboratory-ventilation/), including energy, steam, and chilled water. Here in California, where we have one of the highest rates of electricity ([$0.26 per kWh](https://www.energysage.com/local-data/electricity-cost/ca/los-angeles-county/pasadena/)) in the country, the cost of continuously running a fume hood (which uses between [27,809 kWh](https://fumehoodcalculator.lbl.gov/) and [35,000 kWh per year](https://betterbuildingssolutioncenter.energy.gov/replace-your-fume-hood-and-reduce-electricity-use-at-least-50)) is between [$6,916](https://fumehoodcalculator.lbl.gov/) - $9,100 per year for energy alone, ignoring steam and chilled water costs. As such, Caltech currently spends upwards of $4.9 million - $6.5 million on campus fume hoods per year.

Laboratory fume hoods can be either Constant Air Volume (CAV) or Variable Air Volume (VAV). For [CAV fume hoods](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.energy.gov/femp/articles/fume-hood-sash-stickers-increases-laboratory-safety-and-efficiency-minimal-cost&ved=2ahUKEwi8w-CI_daFAxXfMEQIHdkxDGYQFnoECCIQAQ&usg=AOvVaw23yWqKmibwQmm14GqVXFRa), sash height does not impact the energy consumption. However, for [VAV fume hoods](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.energy.gov/femp/articles/fume-hood-sash-stickers-increases-laboratory-safety-and-efficiency-minimal-cost&ved=2ahUKEwi8w-CI_daFAxXfMEQIHdkxDGYQFnoECCIQAQ&usg=AOvVaw23yWqKmibwQmm14GqVXFRa), sash height has a large impact on energy consumption, with savings of [up to 40% if sashes are closed](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.mygreenlab.org/be-good-in-the-hood.html&ved=2ahUKEwjXsNjViNeFAxUQJEQIHXi8Cs4QFnoECB4QAQ&usg=AOvVaw242mPU-7uSNnMndLtxWcaB). VAV systems are [safer and more efficient](https://iq-laboratory.com/cav-and-vav-fume-hoods-whats-the-difference-2/), and, as such, are one of the [most common HVAC systems](https://www.iesve.com/discoveries/view/32039/vav-systems-in-apachehvac) found in buildings. In 2011, [Caltech started converting CAV fume hood controls to VAV](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://ca.energyservicescoalition.org/Data/Sites/1/documents/casestudies/California%2520Institute%2520of%2520Technology%2520(Caltech).pdf&ved=2ahUKEwjt4pPO8taFAxWghu4BHVQYCLUQFnoECCoQAQ&usg=AOvVaw26ZzaPTFtGJScL5R6RklL8); moving forward, we will presume 100% of fume hoods are VAV due to this commitment, as well as lack of data from a fume hood survey (such a survey would be conducted by a Green Labs Coordinator). Closed sashes are [safest for users](https://www.nationallaboratorysales.com/blog/avoid-these-four-common-fume-hood-mistakes/), as this minimizes exposure to hazards in the hood that can cause harm. However, [anecdotal evidence](https://www.frontiersin.org/articles/10.3389/fbuil.2019.00146/full) suggests that open sashes are “the norm” in most laboratories (this is a common report in many universities).

**There are several programs that Caltech Green Labs could pilot on a small scale, with the potential for great payoffs if expanded across campus (upwards of $149,250 - $1,084,973).**

*Pilot 1: Shut the Sash Campaign*

Starting in 2010 and 2011, respectively, [CU Boulder](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.colorado.edu/ecenter/sites/default/files/attached-files/norberga_i2sl_2014_fume_hood_presentation.pdf&ved=2ahUKEwi1tq2y9taFAxV4IUQIHRRpA7AQFnoECBwQAQ&usg=AOvVaw3DGy_9jdkWsNvDHPqcESj6) and [UC Davis](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.energy.gov/femp/articles/fume-hood-sash-stickers-increases-laboratory-safety-and-efficiency-minimal-cost&ved=2ahUKEwi8w-CI_daFAxXfMEQIHdkxDGYQFnoECCIQAQ&usg=AOvVaw23yWqKmibwQmm14GqVXFRa) have run successful Shut the Sash campaigns, which works to educate and encourage users to shut their sashes with prizes given at the end of the competition for good behaviour. This type of program has minimal costs associated with them (such as the costs of [stickers](https://www.google.com/imgres?q=uc%20davis%20fume%20hood%20stickers&imgurl=https%3A%2F%2Fmarketplace.ucdavis.edu%2FC21642_ustores%2Fweb%2Fuploaded_images%2Fstore_12%2Ffume_hood_stickers.jpg&imgrefurl=https%3A%2F%2Fmarketplace.ucdavis.edu%2FC21642_ustores%2Fweb%2Fproduct_detail.jsp%3FPRODUCTID%3D281%26SINGLESTORE%3Dtrue&docid=SbEPJ8xYSP_DMM&tbnid=6dR1ydhf_9a6lM&vet=12ahUKEwjkxM-9gdeFAxXxIUQIHS9FACIQM3oECBMQAA..i&w=400&h=400&hcb=2&ved=2ahUKEwjkxM-9gdeFAxXxIUQIHS9FACIQM3oECBMQAA), posters, and prizes), and would rely heavily on volunteers going to each fume hood and recording sash height at regular intervals throughout the campaign, but has huge payoffs (CU Boulder and UC Davis see an average sash height reduction of 35%, and worked to identify fume hoods with issues or identify fume hoods that can be hibernated). UC Davis calculated an average savings of [$1,300 per fume hood every year](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.energy.gov/femp/articles/fume-hood-sash-stickers-increases-laboratory-safety-and-efficiency-minimal-cost&ved=2ahUKEwi8w-CI_daFAxXfMEQIHdkxDGYQFnoECCIQAQ&usg=AOvVaw23yWqKmibwQmm14GqVXFRa) (extrapolated, those values for every unalarmed Caltech fume hood amount to $776,100, assuming 100% noncompliance currently). **Even if we are conservative and assume that labs are 50% compliant without this programming, that is still upwards of $149,250 annual savings on energy (assuming 50% compliance exists already, and about $500 energy savings per fume hood).**

*Pilot 2: Motion and Sash Height (MASH) Sensor Campaign*

Alternatively Caltech can implement a Motion and Sash Height Sensor Campaign instead of the Shut the Sash Campaign. In a [study published by MIT](https://www.researchgate.net/publication/355820052_Motion_and_Sash_Height_MASH_alarms_for_efficient_fume_hood_use), the addition of homemade Motion and Sash Height (MASH) sensors, which alarm when the fume hood is open and unoccupied by a user for a set amount of time, encouraged users to close the sash and resulted in a 75.6% decrease in average sash height as compared to control groups that did not have a MASH sensor installed. This resulted in [energy cost reduction of roughly $1,159 per fume hood](https://www.researchgate.net/publication/355820052_Motion_and_Sash_Height_MASH_alarms_for_efficient_fume_hood_use) (if we convert these values to California dollar values for 2024, this will be around $1,491.33 per fume hood). This means that a similar effort could save Caltech roughly $443,612 - $890,324 per year. Each homemade MASH sensor costs around $20-$50 each, meaning an initial investment of up to $29,850 would be required to install sensors on every fume hood on campus. **Again, assuming labs are currently 50% compliant about closing their sashes without the alarms, that is still an annual savings of $221,806-$445,162.**

*Fume Hood Hibernation*

Fume hoods that are still turned on but are not in use contribute large amounts of wasted energy every year. [Cornell](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://ehs.cornell.edu/research-safety/general-laboratory-safety/laboratory-ventilation/fume-hood-hibernation-standard-operating-procedure&ved=2ahUKEwjM8oLzgteFAxWHIUQIHQHgAigQFnoECBIQAQ&usg=AOvVaw1uTC_-GNCHfOpu7uaA_2bW) ([study here](https://www.researchgate.net/publication/338721528_Changing_Behavior_Through_Design_A_Lab_Fume_Hood_Closure_Experiment)), [MIT](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://chemistry.mit.edu/chemistry-news/chemistry-undergraduate-teaching-lab-hibernates-fume-hoods-drastically-reducing-energy-costs/&ved=2ahUKEwjT1a76gteFAxX7OEQIHWjhCFMQFnoECA8QAQ&usg=AOvVaw0UIcMfKgw5Mg6YbNAgPVyN), [Harvard](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://sustainable.harvard.edu/wp-content/uploads/2023/09/FumeHoodWhitePaper-1.pdf&ved=2ahUKEwjT1a76gteFAxX7OEQIHWjhCFMQFnoECBAQAQ&usg=AOvVaw3EYH_HSe16GqdQx0w8lj70), and [University of Georgia (UGA)](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://sustainability.uga.edu/living-lab/living-lab-projects-and-digital-archive/&ved=2ahUKEwjjjPeVhNeFAxVjHEQIHV9gBE8QFnoECA4QAQ&usg=AOvVaw1TQ8hjRukkuqW49zZ8tFUb) have implemented successful fume hood hibernation programs. For this to occur at Caltech, Green Labs would develop a protocol for a quick and safe hibernation, including education, signage, shutdown and startup procedures, and testing procedures. If we assume, similar to UGA, that 3% of fume hoods are able to be shut off, this would amount to an annual savings of between $147,933 - $194,649 (if a fume hood costs $6,916 and $9,100 per year, respectively). **Even if we assume $1,000 savings per fume hood, shutting off 3% of all fume hoods has an annual savings of $21,390.**

If either the Shut the Sash or Motion and Sash Height sensory pilots are conducted, this presents a good opportunity to examine and assess each fume hood to determine if there are any issues with the fume hood (ie. they are not reactive when the sash is opened, or are running with a high face velocity even when the sash is closed), if fume hoods are being used for chemical storage, or if there are fume hoods can be hibernated as they are not currently used. For example, CU Boulder incorporated such checks into their pilot study and found that [10%-20% of fume hoods assessed had an issue](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.colorado.edu/ecenter/sites/default/files/attached-files/norberga_i2sl_2014_fume_hood_presentation.pdf&ved=2ahUKEwi1tq2y9taFAxV4IUQIHRRpA7AQFnoECBwQAQ&usg=AOvVaw3DGy_9jdkWsNvDHPqcESj6).

*High Performance Fume Hoods and Reduced Face Velocity Testing*

High performance fume hoods are becoming standard equipment in newer science buildings, such as Chen. These fume hoods [require 25% less air and can run at lower face velocities](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.labconco.com/articles/reducing-fume-hood-energy-consumption&ved=2ahUKEwiWu62gh9eFAxVOJ0QIHTZLAtwQFnoECCIQAQ&usg=AOvVaw3MbQoY2UOK-ivNdZ20nFW_) than traditional hoods, without compromising safety of users. These fume hoods can save $325 per fume hood a year as compared to conventional hoods. Currently, high performance fume hoods are set at 100 FPM (feet per minute), but [this study](http://www.fumehoodtesters.com/hoodmyth.pdf) suggests that many fume hoods (including many conventional hoods, but especially high performance hoods) can be lowered to 60-70 FPM and still operate safely. Green Labs would coordinate with Safety, EHS, and others to develop protocols for testing to ensure safety and energy efficiency are optimized, but if implemented could impact all 713 fume hoods on campus. **If we reduce even 10% of all fume hoods’ face velocity by 25% (with a savings of $325 per fume hood) this amounts to $23,172.5 per year.**

Refrigeration

*“Chill Up” Ultra-Low Temperature Freezers*

At Caltech, Ultra-Low Temperature (ULT) freezers are commonly set to -80˚C. However, there are [numerous studies](https://www.mygreenlab.org/-70-is-the-new--80.html) suggesting that -70˚C (or warmer) is a safe temperature for most biological samples (a list of samples stored successfully at -70˚C can be [found here](https://docs.google.com/spreadsheets/d/13UvBeoXAhwSHshSYoUDHwcxWiW7qYLnUb-eLwxJbCYs/edit?usp=sharing)). In fact, the only reason freezers are set at -80˚C is due to changing technologies – [fifteen years ago, all ULTs were set to -65˚C or -70˚C.](https://www.mygreenlab.org/-70-is-the-new--80.html) Freezer technology has improved, so researchers can set their freezers to cooler temperatures. However, this additional 10˚C requires [30-40% more energy](https://www.etcc-ca.com/reports/ultra-low-temperature-freezers-opening-door-energy-savings-laboratories), and reduces the lifetime of a freezer. Caltech researchers are currently running a long-term study comparing samples stored at -20˚C, -70˚C, and -80˚C to confirm the results of these studies, with the hopes of convincing researchers to “chill up” their freezers to -70˚C. Furthermore, the NIH is conducting a similar study, with the goal of transitioning all ULTs in their research laboratories to -70˚C.

Caltech has about 150 (+/- 15) ULTs on campus (these numbers are estimated as a recent inventory has not been conducted and facilities is not sure if some freezers are currently operational). Each of these ULTs uses between 11.16 and 19 kWh per day (likely an underestimation due to aging models requiring more energy, perhaps as much as 25 kWh/day) if set at -80˚C. This costs Caltech an average of $116,052-$197,648 per year in energy costs (presuming $0.19 per kWh). If all of these fume hoods were transitioned to -70˚C, and presuming a 30% savings on average, this would save Caltech between $34,816 - $59,294 per year in energy costs. Furthermore, there are many organizations and vendors researching room temperature storage. **Even if we chill up half of all inefficient models (which make up 61 of 159 ULTs) to -70˚C (and assuming they use closer to 19 kWh per day), this is an annual savings of $17,788.20.**

Caltech Green Labs would conduct a complete inventory of ULTs on campus. This inventory would allow explorations opportunities alongside facilities for web-based temperature monitoring (as funding allows), help find older models that are using more energy and can be updated to newer, more efficient, models, help labs explore divestment of old or underutilized freezers, and help labs explore options for room temperature storage or increasing ULT temperatures to -70˚C. All of these initiatives could be offered to labs alongside a point or incentive program.

*Refrigeration Equipment Repair History*

Facilities currently outsources freezer repair to various vendors, and does not currently track the history of specific units. To support better understanding of laboratory refrigeration equipment, Green Labs would help facilities implement a tracking system to record serial numbers of units under repair. This would allow technicians to identify equipment that is problematic or due for replacement. This program would be very simple and inexpensive, but has the potential to reduce biological sample loss, excessive energy use, and costly refrigeration leaks. Refrigerants from older equipment are often [highly potent greenhouse gases](https://www.epa.gov/mvac/acceptable-refrigerants-and-their-impacts), with high Global Warming Potential values, so preventing leaks also benefits Caltech’s greenhouse gas emissions goals.

*Equipment Trade-In Incentives*

Trade-in programs to divest older appliances have demonstrable energy and greenhouse gas savings. As such, Green Labs would continue to support the already-existing Freezer Rebate Program, and investigate other incentives to encourage laboratories to trade in their older freezers. Equipment best suited for such a trade-in program could be identified through the Refrigeration Equipment Repair History program or the inventory program, both outlined above. Furthermore, outreach efforts would encourage users to utilize this program (either for trade-in or when purchasing a new freezer) to encourage sustainable choices.

*Cold Room Upgrade Program*

Built-in cold room equipment can be upgraded to more energy-efficient technologies when certain criteria are met. UAG has developed a program, after which we would model our program, to set criteria, identify appropriate cold rooms, and provide upgrades. This program has the potential to increasing energy savings, reduce sample loss, and provide actionable information about ailing or underutilized models.

Autoclaves

Autoclaves are ubiquitous in research laboratories and are both energy- and water-intensive equipment that are utilized for sterilization of reagents, equipment, and hazardous waste. Many labs are equipped with autoclaves that are [over-sized for the requirements of the lab/building](https://www.mygreenlab.org/autoclaves.html). Here, there are many opportunities to encourage users to utilize these types of equipment more efficiently. For example, neighbouring labs can consolidate loads so that autoclaves are running only full loads. Furthermore, when Caltech laboratories are considering upgrading or purchase of a new autoclave, they can choose to right-size the autoclave (including investigating whether [a non-steam-jacketed model is best for the lab](https://www.priorclave.com/en-us/wp-content/uploads/sites/3/2018/08/Is-Your-Autoclave-Bleeding-You-Dry.pdf), as these models are cheaper, easier to repair, and use [95% less water and 70% less energy](https://www.priorclave.com/en-us/jacketed-or-non-jacketed-autoclave/) than steam-jacketed models). Labs would be encouraged to choose energy- and water-efficient models or to install water-saving devices such as [solenoids or water regulators](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://ehs.princeton.edu/news/greening-the-lab-sustainable-research&ved=2ahUKEwj4mfamk_6FAxVYGjQIHZyvDoo4ChAWegQIBxAB&usg=AOvVaw09yRGJ3rvohZXDZp_1zUsy), or to [retrofit older models](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://suwater.stanford.edu/sites/g/files/sbiybj19876/files/media/file/sem_steamsterilizers_stanford_2013.pdf&ved=2ahUKEwjom4mUmv6FAxXdFjQIHcoyCqAQFnoECCQQAQ&usg=AOvVaw2rqWrnN3zMevpYG0CZcpDL) to be more energy- and water-efficient.

Currently, Caltech has no idea how many autoclaves are currently installed or operating on campus. As such, Green Labs would coordinate with facilities to conduct an inventory. As part of that inventory, model age, usage, and solenoid status would be investigated. Green Labs would also determine the water consumption for each autoclave to better understand the water requirements of each autoclave.

<https://www.priorclave.com/en-us/why-priorclave/autoclave-energy-water-consumption/>

*Solenoid Education and Replacement Program*

Lab personnel would be trained to regularly check solenoid status. [Solenoids](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.duralinesystems.com/Autoclave-Valves-Solenoids-s/201.htm&ved=2ahUKEwiTp42flf6FAxVJAjQIHYC-DA4QFnoECCMQAQ&usg=AOvVaw1c6-HHzh7cDhXtQPmtPZWO) are essential parts of an autoclave that control water flow out of the autoclave. The [solenoid prevents](https://www.rpiparts.com/water-mizer/) water that is too hot from flowing directly into the pipes leading into the building, preventing damage to the building water system. Solenoids sometimes fail, and even if they do not fail, they need to be changed about every 10 years. When solenoids fail, they fail “open”, meaning that they are constantly running cold water to counteract any possible hot water entering the building system. As such, a single solenoid failure can waste [1 – 5 gallons of water per minute](https://www.rpiparts.com/water-mizer/) (1,440 – 7,200 gallons per day), costing Caltech between $3,631.5 and $18,250\* per year per jacketed autoclave. (\*In 2022, Caltech spent $1.2M for water, using 169.7 Mgal, so it costs $0.00707 per gallon). As solenoids typically cost several thousand dollars to replace, Green Labs will investigate funding programs to promote replacement campus-wide. However, the implementation of educational resources to help identify failed solenoids would be inexpensive, as installation of posters on each autoclave has been found to be [effective on several campuses](https://greenlab.uga.edu/initiatives/water-saving/). **However, even if one broken solenoid is replaced this has a minimum savings of $3,631.50.**

*Autoclave Use Reduction and Education Program*

Anecdotally, labs typically use autoclaves very inefficiently (for example, autoclaving a [single box of tips](https://www.mygreenlab.org/autoclaves.html)), and typical labs run [fewer than 5 loads per day](https://www.priorclave.com/en-us/wp-content/uploads/sites/3/2018/08/LabDesign_Dec2016.pdf). Each jacketed autoclave run uses [44 – 50 gallons of water](https://www.priorclave.com/en-us/why-priorclave/autoclave-energy-water-consumption/) per use (if an autoclave is older than 10 years old, It can use up to [90 gallons per cycle](https://www.priorclave.com/en-us/why-priorclave/autoclave-energy-water-consumption/)), and uses between [5,000 – 50, 000 kWh per year](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://consteril.com/sterilizer-total-cost-of-ownership/&ved=2ahUKEwi6qLOOnf6FAxVnITQIHeKhCgMQFnoECCgQAQ&usg=AOvVaw28GVt0B2ag8uVYbZL_sY-t) in energy. As such, it is imperative that users are trained to utilize autoclaves more effectively by running only full loads (perhaps by collaborating with another lab, or by having an autoclave run schedule), reducing purchase of new autoclaves and instead sharing autoclaves across laboratories. An autoclave share education program has the potential to save water and energy on campus, and calculations of water and energy savings would be conducted as part of such a program by Green Labs and facilities. This education program would be simple to implement – requiring only training materials (such as slides) and signage.

The autoclave share education program also offers an opportunity to inventory autoclaves on campus, retire, retrofit, or replace older models, as well as increase awareness of efficient autoclave use and increase understanding of how to use autoclaves properly (which will reduce user error and prevent costly maintenance).

**Waste Reduction and Recycling Initiatives**

Caltech sends 1,800 tons (at a cost of $901,000) to landfill each year. Laboratories contribute significantly to this value, with lab researchers [typically producing 15x as much plastic waste alone as the average person](https://www.nature.com/articles/528479c). Green Labs would like to conduct a waste audit to determine the amount and kinds of waste typically developed by laboratories on campus, and to understand the dollar value associated with this waste. A waste audit will also inform the kinds of [work that can be done](https://lions-talk-science.org/2022/05/18/research-laboratories-brought-plastic-into-this-world-now-can-they-do-their-part-to-take-it-out/), including reduction, reuse, and recycling programs, all of which will contribute to reduced landfill costs. The initiatives described below have the potential to save Caltech a minimum of $130,655, though exact estimates of some projects are impossible to make.

Laboratory Plastics Recycling

Laboratory waste audits will inform work that can be done to reduce plastic waste, including reduction of reliance on plastics, replacement with more easily recyclable materials (like glass), reuse of plastics in experiments (including single-use plastics, such as by the utilization of [pipette tip washers](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://grenovasolutions.com/tipnovus-4-2/&ved=2ahUKEwih8cj2pv6FAxU6J0QIHUVSB64QFnoECBMQAQ&usg=AOvVaw1htAIiTkFmZ4qtvbJ6cliv)), and transparent and reliable recycling of plastics from our campus.

Green Labs has successfully implemented a recycling program targeting a specific type of lab plastic waste: [pipette tip box and wafers](https://greenlabs.caltech.edu/green-labs-pilot-programs). Green Labs partnered with two vendors, USA Scientific and Genesee, to install recycling bins in several BBE buildings to divert this plastic either for reuse in other labs, or recycling programs. In the first year alone, over 1120 lbs of plastic waste that would have otherwise not been recycled was diverted from landfill. This has provided Caltech with an estimated savings of $618 in waste disposal fees, and has cost $50 to purchase cardboard recycling bins and bags. The vendors we partner with pick up the waste when they visit campus and drop it off on their way home from the campus, thus making this program free of continuing fees, and free of carbon emissions (since these routes are utilized by the vendors with or without the plastic waste). This pilot program has shown us that 1) labs want to recycle 2) labs are willing to collect plastic waste in their labs and bring it to a centralized location in their buildings, and 3) labs are capable and willing to sort this plastic waste effectively. Growing other programs along this type of paradigm show great potential, though the potential costs of establishing permanent programs will increase as we exceed the capabilities of volunteers to reasonably handle the plastic waste.

Green Labs will also investigate paid-for recycling programs, such as those through [TerraCycle](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://shop.terracycle.com/en-US/products/rigid-lab-plastics-zero-waste-box&ved=2ahUKEwiQ2vbyqP6FAxUqC0QIHQ3vDOUQFnoECB4QAQ&usg=AOvVaw1g8HFSUR4SZUnOBF_XjbXm) or [PolyCarbin](https://polycarbin.com/pages/recycle). These programs require labs to ship non-hazardous lab plastics to specific facilities, but offer the opportunity to recycle items that would otherwise be impossible to recycle through municipal programs (including lab plastics or even [gloves](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://shop.terracycle.com/en-US/products/disposable-gloves-zero-waste-box&ved=2ahUKEwj247b9qP6FAxXJIEQIHTLPBB0QFnoECBUQAQ&usg=AOvVaw2HzH1nnotBwwSZ3moBevz5)). If these programs were to be [adopted campus-wide](https://www.theguardian.com/environment/2019/nov/10/research-labs-plastic-waste), significant training protocols and educational tools would be required to ensure the health and safety of the users, transportation teams, and recycling teams. As such, Green Labs would collaborate with EHS, facilities, and hazardous waste management teams to ensure successful decontamination of plastics, development of clear guidelines on what can be recycled, and what the vulnerabilities and benefits of such a program would be.

If even 5% of landfilled waste is made up of recyclable laboratory plastics, a large-scale lab plastics recycling program would result in an annual savings of around $45,000. Furthermore, some plastics, depending on the type and market for each type of plastic, could potentially generate income for Caltech. More investigation is needed to verify the potential cost-benefits to such programs. **Initial estimates, if we could divert just 1% of lab plastic waste, indicate an annual savings of $9,000.**

*Laboratory Pipette Tip Cycle Program*

The Beckman Institute recently acquired an opto-fluidics instrument, the [Beacon](https://brukercellularanalysis.com/), manufactured by Berkeley Lights. This instrument enables culture, manipulation, assay, and recovery of thousands of individual cells using light, reducing traditional timelines for cell culture work from months to days. This instrument alone requires a minimum of 4,800 pipette tips per plate-based assay. Other labs on campus can produce an estimated [36,000 pipette tips a year](https://bme.gatech.edu/bme/news/tip-cycle-program-aims-reduce-single-use-plastics-campus-labs). This means that Caltech produces over 2.5 tons of pipette plastic waste a year, and the purchase and disposal of so many tips requires a significant amount of laboratory budgets for consumables. As such, reuse of these single-use plastics has huge potential benefits to laboratories (saving anywhere from $8,300 to $22,000 or more per year), as well as reduction of water use and greenhouse gas emissions (The production of 960 pipette tips releases [1.75 kg](https://grenovasolutions.com/grenovas-technology-proven-to-reduce-the-carbon-footprint-of-pipette-tips-and-boost-lab-sustainability/) to [5 kg of CO2](https://www.sciencedirect.com/science/article/pii/S2351978918302142/pdf?crasolve=1&r=8051ad234ce62ef8&ts=1694453821996&rtype=https&vrr=UKN&redir=UKN&redir_fr=UKN&redir_arc=UKN&vhash=UKN&host=d3d3LnNjaWVuY2VkaXJlY3QuY29t&tsoh=d3d3LnNjaWVuY2VkaXJlY3QuY29t&rh=d3d3LnNjaWVuY2VkaXJlY3QuY29t&re=X2JsYW5rXw%3D%3D&ns_h=d3d3LnNjaWVuY2VkaXJlY3QuY29t&ns_e=X2JsYW5rXw%3D%3D&rh_fd=rrr)n%5Ed%60i%5E%60_dm%60%5Eo)%5Ejh&tsoh_fd=rrr)n%5Ed%60i%5E%60_dm%60%5Eo)%5Ejh&iv=129fae6e1069b5641697d86d776a03ad&token=6435313732393531383763343961376632353537353731383336336630376631346166386366343834633035363736306536663464323230623131353331323837356530646561663161633735656664666362376232616430353a623138333337353033653866633630353834383337353362&text=&original=3f6d64353d3839396462663834313261346536306664613638636461313838663034343039267069643d312d73322e302d53323335313937383931383330323134322d6d61696e2e706466) and uses [89 L of water](https://www.mdpi.com/1996-1944/13/16/3541), whereas washing 960 tips only produces 0.5 kg of CO2, and consumes [25 L](https://www.scrum-net.co.jp/content/download/5155/78223/version/1/file/Poster-CDC-TipNovus.pdf) of [water](https://wwwn.cdc.gov/nchs/data/nhanes/2013-2014/labmethods/TSNA_H_MET.pdf)).

The Beacon instrument utilizes a robotic liquid handler that can be integrated with the [Grenova TipNovus pipette tip washer](https://grenovasolutions.com/?utm_term&utm_campaign=Pipette&utm_source=adwords&utm_medium=ppc&hsa_acc=9524309256&hsa_cam=9350631258&hsa_grp=129097610828&hsa_ad=512878319480&hsa_src=g&hsa_tgt=dsa-1217850679836&hsa_kw&hsa_mt&hsa_net=adwords&hsa_ver=3&gad=1&gclid=CjwKCAjwrranBhAEEiwAzbhNte0lAh-gvveFPAQ02RkgNrxDzig9u_2QYElceXsEJXq-3AONCh1HeBoCw0QQAvD_BwE) system, meaning that an underutilized liquid handler would be utilized more effectively, and that the cost of automation for a pipette tip washing system would be minimal. The Grenova system has been successfully integrated and [validated](https://grenovasolutions.com/tipnovus-4-2/) by several universities including [Georgia Tech](https://tipcycle7.wixsite.com/tipcycle), the [NIH](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://nems.nih.gov/Documents/Newsletter/2020/12_December_2020/Staff_Spotlight_NCATS.pdf&ved=2ahUKEwi387mrtv6FAxVGLEQIHZSFAM8QFnoECCwQAQ&usg=AOvVaw1xLL4n7UbI5evx5tsyk_up), and the [CDC](https://wwwn.cdc.gov/nchs/data/nhanes/2013-2014/labmethods/TSNA_H_MET.pdf) (who also validated that the accuracy and precision of pipette tips is no different after 11 wash cycles as compared to virgin tips). **If this technology were to be integrated into the Beacon robotic liquid handler, it could, at minimum (with 10 wash cycles per tip) save upwards of $75,325 annually for the Beacon laboratory, though this technology could certainly serve more than one lab, making the annual savings much more.**

Laboratory Glassware, Equipment, and Chemical Share Program

Laboratories may purchase large amounts of a chemical, additional equipment, or glassware, in an effort to use up startup or grant funds before they expire. These bulk purchases are often preferable as they lower unit costs, and can be accompanied by larger discounts and lower delivery fees. However, this results in chemical, glassware, and equipment “stockpiles” that may never be fully used. In the case of chemicals and equipment, these items later need to be safely disposed of, which potentially costs even more than the initial bulk purchase savings. Green Labs will also support organizations such as [Million Advocates for Sustainable Science](https://www.sustainablescienceadvocates.org/), an organization challenging science funding agencies worldwide to encourage sustainability in research.

Green Labs would investigate and facilitate the development of a Glassware, Equipment, and Chemical Share program, including finding space on campus to store such items. This would prevent over-purchasing of unnecessary goods, and also potentially benefit labs that may not otherwise have access to particular goods. Green Labs would also collaborate with programs such as the [Lab Equipment Access Program (LEAP)](https://leap.caltech.edu/), a program that takes unnecessary lab supplies and disperses these goods to underserved communities, such as high school student classrooms. Such programs not only benefit underserved communities, reduce reliance on fluctuating supply chains, but also save labs potentially millions of dollars in unnecessary spending.

Composting

*Composting Animal Cage Bedding*

Caltech currently houses between 4,000 and 6,000 mouse cages at any given time. Each cage requires about 120 g of bedding which is changed about every other week. This means Caltech is currently disposing of over 18,720 kg (20.6 tons) of bedding per year, costing about $10,330 to dispose of. This waste stream has been deemed safe by numerous other universities (including [UGA](https://greenlab.uga.edu/initiatives/waste-diversion/), [CU Boulder](https://colostate.pressbooks.pub/cvmbsgreenlabsresourceguide/chapter/green-labs-at-csu/), [UAB](https://www.conference2023.i2sl.org/green-labs), and [CSU](https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.fm.colostate.edu/recycling/&ved=2ahUKEwjez96aw_6FAxUOKEQIHRRdCyo4ChAWegQIFBAB&usg=AOvVaw0hW5ZWYdreUQHbYpKxtGnO)) as a welcome, safe, and reliable source of compost. Green Labs will collaborate with these universities to understand the approval process, how to segregate waste, how to train facilities, and potential cost-benefits of an animal bedding composting program. **Even if half of animal bedding could be diverted, this would be an annual savings of $5,165.**

*Composting in Laboratory Kitchen Areas*

Food waste in laboratory kitchen areas is an underutilized resource on campus. In 2023, Green Labs funded the installation of 3 [Lomi tabletop composters](https://lomi.com/products/lomi?utm_source=google&utm_medium=cpc&utm_campaign=brand&nbt=nb%3Aadwords%3Ag%3A16592870122%3A151339127228%3A630911847281&nb_adtype=&nb_kwd=lomi&nb_ti=kwd-1309544676&nb_mi=&nb_pc=&nb_pi=&nb_ppi=&nb_placement=&nb_li_ms=&nb_lp_ms=&nb_fii=&nb_ap=&nb_mt=p&gclid=CjwKCAjwov6hBhBsEiwAvrvN6NxNdlKftJjl3NbUpUgk0QtAUeG64EG7kYZIlsiHSH4t1sQ6KMZ9ChoCNjoQAvD_BwE&campaignid=16592870122&adgroupid=151339127228&targetid=kwd-1309544676&creative=630911847281&network=g&device=c&utm_source=google&gclid=CjwKCAjwov6hBhBsEiwAvrvN6NxNdlKftJjl3NbUpUgk0QtAUeG64EG7kYZIlsiHSH4t1sQ6KMZ9ChoCNjoQAvD_BwE) (with an initial cost of around $350 each) in Chen kitchen areas, to determine the amount of food waste generated in shared kitchen spaces. Lomi tabletop composters were an ideal technology for this pilot, as they were easy to install, relatively inexpensive, did not produce “smelly” composting areas (a major concern for users), and allowed for educational tools to be developed. Maintenance of the Lomis required three volunteers to run the machines several times a week, turning food waste into compost dirt, and dropoff of the dirt to facilities once a month. Caltech grounds is able to utilize the compost dirt to fertilize the campus gardens, meaning the food waste stays on campus, reducing transportation and custodial costs, reduces custodial burden as they are not required to deal with as much food waste in waste streams, and reduces the amount of compost needing to be purchased for grounds maintenance.

In the first year, the [Lomi composting pilot program](https://greenlabs.caltech.edu/green-labs-pilot-programs) diverted over 1777 lbs of food waste, converting that waste into 355 lbs of compost dirt. **This has provided Caltech with an estimated savings of $445 in waste disposal fees.** Furthermore, the Lomi machines were so popular that two more have been installed across BBE buildings, with the potential for more in future months. This program, among others, also allowed education and outreach from the burgeoning Green Labs program, encouraging over 100 people to join the Green Labs network, and over 20 labs to become Green Labs Certified.

This pilot has also provided data that the Graduate Student Council (GSC) Sustainability Committee has utilized to establish large-scale composting programs for student housing buildings, with the goal of creating a campus-wide composting program accessible to everyone in the coming years. Green Labs will support these endeavours in whatever way possible.

Sustainable Event Initiatives

Hosting zero-waste events and utilizing vendors that promote sustainable practices (such as having vegan or vegetarian options, farm-to-table models of food production, or compostable cutlery) has never been more important. As such, Green Labs meetings and events strive to be zero-waste and sustainable. As such, we put together several Guides showing researchers how easy it is to run a sustainable event. These resources include restaurant suggestions ([Sustainable Restaurants Guide](https://greenlabs.caltech.edu/documents/26726/Sustainable_Restaurants_Resources_V3.pdf), [Sustainable Coffee/Breakfast/Dessert Guide](https://greenlabs.caltech.edu/documents/27161/Sustainable_Coffee_Breakfast_and_Dessert_Resources.pdf)), a [Tips and Tricks for a Sustainable Event Guide](https://greenlabs.caltech.edu/documents/26727/How_to_plan_a_sustainable_event.pdf), [a Sustainable Event Vendor Agreement](https://greenlabs.caltech.edu/documents/26725/Vendor_Agreement.docx) (asking vendors participating at events on campus to behave sustainably), and a [Holiday Checklist](https://greenlabs.caltech.edu/documents/27168/Holiday_Checklist_2.pdf) (ensuring you are not wasting energy during winter breaks or other holidays).

We hope to further these initiatives by developing a Sustainable Event Certification (like this one from [UCLA](https://www.sustain.ucla.edu/green-events)), working with Caltech Dining Services to offer more options to host sustainable events on campus. Further, we hope to support Graduate Student Council initiatives promoting sustainable events, including potential partnerships with the Plant-Based Universities group (projects may include developing menu signage indicating how sustainable each meal offered is).

**Purchasing / Packaging Reduction**

Green Labs would like to partner with Purchasing to examine current purchasing patters and policies at Caltech. Green Labs would also like to coordinate on contracts with vendors to see if they can be encouraged to reduce the amount of packaging (such as Styrofoam) that is sent to campus, if they would participate in buy-back/send-back programs for packaging, if they would transition away from Styrofoam packaging, or if they would be willing to investigate room-temperature stable reagents. A few examples of good and easy-to-use programs include Styrofoam return programs from [NEB](https://www.neb.com/en-us/nebinspired-blog/recycling-styrofoam) and [Signa-Aldrich](https://www.sigmaaldrich.com/US/en/services/support/recycling/polystyrene-cooler-return-program); [Corning, Falcon, and Axygen product packaging](https://corning.mailthisback.com/) return program, and printer ink/toner recycling programs such as [Office Depot](https://www.officedepot.com/l/services/ink-and-toner-cartridge-recycling), or [HP](https://www.hp.com/us-en/hp-information/recycling/ink-toner.html); various companies also allow labs to [send back used coffee pods](https://www.nespresso.com/us/en/how-to-recycle-coffee-capsules).

These efforts would ensure best-practices that minimize energy- and water-intensive appliances from being purchased, working towards establishing incentive programs for such purchases, and reduce the amount of packaging material waste before it arrives on campus, preventing Caltech from absorbing the costs of disposing of these materials. There is also potential here for reuse programs of packaging materials, such as Styrofoam, which is a convenient packaging material for many labs that need to send samples or material requiring dry ice for transport. Estimates for the annual dollar-value savings for these initiatives are difficult to make, but if we can reduce costs by at least 10% that would mean an annual savings of $XXX.

**Green Chemistry and Safety Initiatives**

Collaborations with several universities (including UC Santa Cruz, UC Davis, Arizona State University, and UGA) suggest there is a strong, positive correlation between safety compliance and Green Labs initiatives. These programs not only improve lab safety, they also improve lab safety compliance and improve safety inspection outcomes. Furthermore, they promote compliance and best practices for hazardous materials, provide an opportunity for additional safety training, and prevent incidents such as plumbers encountering hazardous wastes in sink p-traps, for example.

One way to improve safety in labs is to remove hazardous materials from research work when possible; this will not only reduce the hazards lab personnel and EHS workers are exposed to, this will also reduce costs of hazardous waste disposal (which has increased by 15% since 2021), and reduce the personal protective equipment burden or reliance on energy-intensive processes or fume hoods. NUMBERS HERE? Compliance for researchers includes following a formal Chemical Hygiene Plan (required under EPA and other Federal regulators), which can be achieved through two initiatives: chemical substitution and chemical sharing (see above Laboratory Glassware, Equipment, and Chemical Share Program section for a description.). While it is difficult to estimate monetary savings for this initiative, we can tentatively set a goal of reducing costs by 10%.

Chemical Substitution

There are often simple solutions to improve the safety of researchers when examining old protocols, developing new protocols, or developing teaching modules. Some resources include [My Green Lab](https://www.mygreenlab.org/green-chemistry.html) and [Beyond Benign](https://www.beyondbenign.org/), the [12 Principles of Green Chemistry](https://pubs.acs.org/doi/full/10.1021/acssuschemeng.6b02399) that allow researchers to compare greener alternatives systematically. There are also several green chemistry tools available, including those from [Millipore Sigma](https://www.sigmaaldrich.com/US/en/services/software-and-digital-platforms/dozn-tool), or the [US EPA Chemical Substances Inventory](https://www.epa.gov/tsca-inventory). These programs and resources would be utilized and built upon to establish a chemical substitution program at Caltech. This program would encourage users to explore safer alternatives, examine common practices, and provide chemical assessment tools to encourage labs to switch to available green alternatives where appropriate. Funding opportunities could be investigated to offset any unanticipated costs associated with transitioning to greener alternatives for labs that are Green Labs Certified. Again, for this initiative it is difficult to estimate monetary savings, but we can set a tentative goal of saving labs 10% in hazardous waste fees.

Chemical Sharing

See above Laboratory Glassware, Equipment, and Chemical Share Program section for a description. Certified Green Labs would be required to participate in this program, and non-Certified labs would be encouraged to participate.

**Incentives**

Currently, any labs that submit Green Labs Certification forms receive a plaque posted outside their lab spaces showing their Certification level and recognizing their participation in the Green Labs Program. These labs are also highlighted on the Green Labs website and are invited to Certified-exclusive events several times a year. Programming and educational tools are currently being developed to encourage labs to become even more sustainable in areas where they felt they could use improvement. We hope that each Certified lab will re-Certify their commitments every year, and participate in sustainable events or programs that improve their laboratories.

Additional incentives could be targeted towards graduate and undergraduate students, as these researchers have the potential to impact their research environments the most and will hopefully bring any sustainable ideas to future research environments. Similarly, staff, PI, and post-doc incentives have the potential to significantly improve long-term environments of researchers on campus, as these researchers will potentially remain on campus for long periods of time, and will be invested and interested in sustainable lab programs. This continuation of knowledge and training is essential for making any Green Labs program successful at Caltech. Incentives could include competitions, prizes or discounts at local businesses, and free educational/training tools to name a few. Professional Development opportunities should be developed, and made available to all researchers to encourage the development of sustainability-minded research and community leaders that promote laboratory best practices.

Collaborations between researchers in other departments, such as the Glassware, Equipment, and Chemical share program, allow development of relationships between various departments and promote safe and efficient practices campus-wide.

Furthermore, to maximize sustainable initiative adoption, Caltech could investigate the potential for payback programs for Certified labs, such as reduction of overhead costs depending on level of commitment for various sustainable programs (such as chilling up ULT freezers).

**Administration and Funding**

The Green Labs group is currently run entirely on volunteer time and energy, and is funded entirely by BBE. At the moment, the impact of this group is relatively small as there are no opportunities to talk to labs one-on-one and discover issues, answer questions, coordinate efforts across multiple divisions (as it is housed and funded solely by BBE), and investigate issues (such as inventories of autoclaves) that impact the entire campus.

Furthermore, the Resnick Sustainability Center is being built to house not only researchers, but teaching laboratories. These laboratories will serve critical roles in the education of all undergraduate and graduate researchers, and which will require development of targeted sustainability curriculum. A Green Labs Coordinator would be crucial to develop and integrate sustainability curriculum and training. This curriculum could also be incorporated into Ethics and onboarding training all researchers are required to undergo. Further Certificates (like this one through UBC) could be developed such that researchers could be Certified sustainability champions on campus, increasing impact of sustainability initiatives, improving safety compliance, and creating professional development opportunities.

A Green Labs Coordinator would also have roles in numerous areas including (but not limited to): promoting zero-waste initiatives, if Caltech chooses to adopt such initiatives; working with the Graduate Student Council Sustainability Committee on their ambitious goals; providing internship opportunities for students; conducting lab clean up initiatives and space allocation surveys; running the Glassware, Equipment, and Chemical Exchange program; participating in procurement negotiations; work with EHS and biosafety to make labs not only safer but also more sustainable (Green Labs Representative roles could even be incorporated into already-existing Safety Officer roles); working with facilities to reduce service requests, conduct inventories, and increase oversight; working on long-term projects such as chilling up ultra-low temperature freezers, fume hood and freezer inventories and upgrades, and autoclave share programs.

As such, in order to safely and effectively implement the recommended initiatives, the Green Labs program suggests hiring a full-time employee to guide this program. This position could be housed either under the Sustainability or EHS departments. The Green Labs program will need to be led by someone experienced with regulatory and technical issues (such as fume hood testing, biological safety, hazardous material disposal etc.), and should be familiar with wet lab work, and with researchers on campus. Student and volunteer help will be necessary to support data collection, outreach efforts, signage placement, conducting surveys etc. However, a volunteer group will not be able to bring necessary continuity and expertise that would be embodied by a qualified, full-time Green Labs Coordinator.

Funding could be received from the Resnick Institute, the Department of Sustainability, and/or Biosafety or EHS departments. Initiatives here represent an annual reduction of (at minimum) $756,279 in energy, water, and waste disposal costs. These cost reductions would more than pay for a full-time Green Labs Coordinator position, as well as provide funds for expansion and development of both pilot and permanent Green Labs programs. To see the full potential of the proposed programs, we expect it will take 5-10 years to get all programs running effectively.

**Appendix**

**Aspirational Peer University Green Labs Programs Descriptions (Extended)**

[Cornell University](https://sustainability.weill.cornell.edu/green-labs) has a well-established Green Labs program including (but not limited to) guides on how to make labs greener, eco-friendly alternatives to non-sustainable lab products, and ultra-low temperature freezer maintenance guides, to name a few. Their program also focuses on lab waste and recycling, autoclaves, energy consumption and statistics (for example they have a Shut the Sash program), and the amalgamation of resources for even more sustainable action.

[Johns Hopkins University](https://sustainability.jhu.edu/engage/green-labs/) Green Labs program utilizes the (paid-for) My Green Labs Certification program. This program also supports individualized green labs training (ranging from social and environmental impacts of research, role of scientists as responsible members of society, and skills and professional development relating to green labs best practices) for departments, programs and labs. JHU also created a [Green Labs Best Practices Guide](https://sustainability.jhu.edu/wp-content/uploads/2022/12/Best-Practices-Light-for-Web.pdf) covering topics including equipment plug loads, fume hoods, biosafety cabinets, freezers, green chemistry, waste reduction, and infrastructure. Further support is offered for the International Freezer Challenge, lab waste and recycling, and equipment share programs.

[Massachusetts Institute of Technology Green Labs Program](https://ehs.mit.edu/sustainable-labs/) has focused on several areas of sustainability including recycling and waste reduction, pollution prevention, chemical inventories, safe and sustainable labs, cold storage, and green chemistry. In fact, their team is so dedicated to green chemistry and chemical substitution they developed the [Green Alternatives Wizard](https://ehs.mit.edu/green-chemistry/), which is a database allowing comparison of safer or less energy intensive chemical alternatives or processes.

[Pennsylvania State University](https://sustainability.psu.edu/programs/sustainable-labs/) Green Labs program was recognized by the International Institute for Sustainable Laboratories for the development of the Sustainable Lab Ambassador scholarship program that works to support research labs as they transition to more sustainable practices. This program utilizes the (paid-for) My Green Lab Certification program to Certify and assess labs in 14 target areas.

[Stanford University](https://sustainable.stanford.edu/operations/buildings-grounds/labs) has a green labs program focusing on green chemistry, energy, lab waste, and water conservation. They have developed Green Labs online training modules that educates researchers about sustainable lab supply purchasing, chemical use, energy efficiency, proper waste disposal, water consumption, and more.

[Texas A&M University – College Station](https://semc.tamu.edu/greens-labs-certification-program/index.html) has developed a Green Lab program that labs can apply to online and are awarded points in fifty categories (including Styrofoam and glove recycling, chemical and equipment and chemical sharing, freezer maintenance, room temperature DNA storage, and mercury thermometer exchange, to name a few), alongside a lab walkthrough with EHS to confirm a checklist of items and initiatives. This Certification needs to be resubmitted every two years to maintain or update Certification level.

[University of Alabama at Birmingham](https://www.uab.edu/sustainability/greenlab) Green Labs program focuses on reduction of energy, water, material goods, and hazardous chemicals. They have a Green Labs Certification program that assesses labs alongside a partnership with EHS, and provides generalized guidelines that allow for individual labs to develop additional practices specific for their labs. Each lab selects a Green Labs Representative that takes a survey and encourages at least half of their lab to also complete the survey, then this assessment is reviewed and changes are suggested. Once changes are implemented, labs are granted Certification at five levels depending on how successfully suggested changes were implemented. Further resources include a [Green Labs Primer](https://www.uab.edu/sustainability/images/Documents/green-labs-onboarding.pdf) to introduce new researchers to Green Labs practices, [Lab Recycling and Reuse Program](https://www.uab.edu/sustainability/greenlab/lab-recycle), and [ULT Freezer Reservation program](https://www.uab.edu/sustainability/greenlab/reserve-a-ult-freezer).

[University of British Columbia](https://sustain.ubc.ca/green-labs) Green Labs program supports researchers to reduce energy and water use, improve lab recycling, access funding, implement sustainable solutions, and facilitate community conversations about best practices. This program also includes resources for Chill Up Challenge, Shut the Sash program, Waterless Condenser rental program, freezer rebate program, international freezer challenge, and free outlet timers. They certify labs through the (paid-for) My Green Labs Certification program, and offer a [Lab Sustainability Course](https://sustain.ubc.ca/programs/green-labs-program/lab-sustainability-course) and [Sustainability Coordinator Programs](https://sustain.ubc.ca/programs/sustainability-coordinator-program) to better engage and train interested researchers. Though this university is in Canada, we felt inclusion of this program was necessary.

[University of California Berkeley](https://sustainability.berkeley.edu/engage/green-labs-certification) Green Labs program began around 2020, where they set goals for energy-saving technology, engagement, procurement strategies, waste elimination, and water reduction. Their Certification Program allows labs to achieve credits in areas of energy efficiency, water efficiency, waste reduction, chemicals, purchasing, and education. This university also developed useful [Green Labs Guide](https://drive.google.com/open?id=0B1oDtpwVEFRMTXgwNXNpSE5fRDQ5WTNIbmMyckJ5a2VPVUFv) and [Green Labs Product Guide](https://docs.google.com/document/d/19n6_e1HtE65utVjicacrOAHRzib1WGvh9JBO3JMc3b8/edit) for labs to use as models of sustainable practices. UC Berkeley also has a [Zero-Waste commitment](https://sustainability.berkeley.edu/engage/zero-waste), of which Green Labs plays a significant role.

[University of California Davis Green Labs Program](https://sustainability.ucdavis.edu/green-workplace) has developed an exemplary Green Labs Certification program wherein labs are awarded two-year Bronze, Silver, or Gold Certifications depending on how many points are achieved in various categories (ranging from community engagement, energy, fieldwork, green chemistry, travel, waste, and water initiatives). They have a minimum expectation that Lab Champions spend at least four hours per month working on initiatives for the Green Labs program. Furthermore, they have developed resources not only for Green Labs, but also for Green Workplaces (including Green Home Office and Green Study Space).

[University of California Los Angeles](https://www.sustain.ucla.edu/green-labs/) Green Labs program offers a comprehensive Green Labs Certification program that includes an assessment of current practices that produces recommendations and educational tools on how each individual lab can reduce environmental impact. After three months of implementing the recommendations and tools, a reassessment is conducted and certification granted (depending on progress). Their program also offers resources on freezer maintenance and updating, waste disposal, [green event certification](https://www.sustain.ucla.edu/green-events), and they provide grant money for sustainable projects with their [Green Initiative Fund](https://www.tgif.ucla.edu/), as well as having a [zero waste commitment](https://www.sustain.ucla.edu/zero-waste/) and a [green buildings](https://www.sustain.ucla.edu/green-buildings/) commitment, among others.

[University of California Irvine](https://sustainability.uci.edu/green-lab/) Green Labs program is one of the first formal programs ever developed. This program has resources ranging from a [Welcome Guide and Checklist](https://sustainability.uci.edu/wp-content/uploads/2022/03/Welcome-Guide-UPDATED.pdf), to downloadable signs and labels, guidelines for sustainable remote research, energy efficiency, water conservation, waste reduction, green chemistry, and procurement, alongside their (paid-for) My Green Labs Certification program. UC Irvine also hosts [sustainability staff training](https://sustainability.uci.edu/education/staff-professional-development-and-training/). Furthermore, UC Irvine is the homebase for many educational tools such as the [Smart Labs Program](https://www.ehs.uci.edu/energy/index.php), encouraging labs to build better and more sustainable laboratories, and assess needs for things such as energy consumption empirically.

[University of California Merced](https://sustainability.ucmerced.edu/get-involved/faculty-and-staff/green-lab-program) Green Lab Program utilizes the (paid-for) My Green Labs Certification program. This group has also developed a [Green Lab Action Plan](https://ucmerced.box.com/s/r0c1olhr59xcvvfhnf114ppe3dflv58r), and a [Green Offices Program](https://sustainability.ucmerced.edu/get-involved/faculty-and-staff/green-offices-program), and works with labs to inform, collect best practices, engage labs, develop initiatives and assess areas of improvement to adjust research efficiency.

[University of California Riverside](https://sustainability.ucr.edu/green-labs-program) Green Labs program was developed in 2014. Labs are certified with the (paid-for) My Green Labs Certification program, and Green Labs also independently works with labs to increase efficiency in water and energy use, and encourage proper waste management practices. This program also offers rebates on new energy-efficient equipment, shared instrument programs, surplus redistribution, chemical inventories, waste pickup services, International Freezer Challenge, and is working on glove recycling programs, autoclave efficiency research, and Styrofoam recycling programs.

[University of California San Diego](https://sustain.ucsd.edu/involve/green-labs.html) Green Labs program is working to assist labs in reducing their resource use and improving education and engagement efforts surrounding: electricity, lighting, cold storage and freezer management, fume hoods and ventilation, water, inventory management, recycling, waste reduction, hazardous waste disposal, green chemistry, travel, field work, community, purchasing, incentive/rebate programs, utility usage reporting, autoclaves/glass washing, and education. Their Green Labs Certification program is currently on pause, with a revamped program expected to release in Fall 2024. This group has many useful resources including laboratory recycling signage, sustainable lab products and equipment lists, sustainable practices guidelines, [ChemCycle](https://blink.ucsd.edu/safety/research-lab/hazardous-waste/chemcycle.html#How-to-use-Chemcycle) chemical recycling and redistribution program, and many more. Green Labs program also supports [Green Office](https://sustain.ucsd.edu/involve/green-office.html), [Green Classroom](https://sustain.ucsd.edu/involve/green-classroom.html), [Green Events](https://sustain.ucsd.edu/involve/green-events.html), [Green Residence](https://sustain.ucsd.edu/involve/green-residence.html), [Green Grads](https://sustain.ucsd.edu/involve/green-grads.html), and [Zero Waste](https://facilityservices.ucsd.edu/sustainability/zero-waste.html) efforts.

[University of Colorado Boulder (CU Boulder) Green Labs Program](https://www.colorado.edu/ecenter/programs/cu-green-labs-program) is one of the oldest and best-run programs in the US. This group has developed resources for labs in various categories including energy, water, and waste solvent re-use, equipment sharing and efficient space use, funding connections, social justice, and fervently support the International Freezer Challenge, as they are one of the original competitor universities and have one of the longest and most established programs in the US. Their program also provides resources for the Green Labs Community to establish their own programs, and to answer some commonly-asked questions. This program awards Green Lab Awards based on nominations from the community.

[University of Georgia Green Labs Program](https://greenlab.uga.edu/) includes initiatives focusing on energy saving, procurement, waste diversion, and water savings. This group is also focused on making complete and accurate Life Cycle Analyses of various products, including gloves (for which they have spent over four years researching the purchase of ethically-sourced gloves for their laboratories.)

[University of Texas at Austin](https://ehs.utexas.edu/research-labs-clinical/green-labs) Green Labs program has resources, including a [Green Labs Manual](https://utexas.box.com/s/bflwh5mpyn67y7yk5eawiem2syankclt), geared towards tackling lab freezers, minimizing waste, recycling, chemical surplus, green chemistry, water conservation, and energy conservation. This program also offers [sustainability grant proposal funding](https://ehs.utexas.edu/research-labs-clinical/green-labs/sustainability-grant-proposals). This program is unique in that it is within EHS, which has allowed it to work with both labs and EHS to make labs safer, compliant, and sustainable. Furthermore they have developed the [EHS Green Labs Leader Badge](https://ehs.utexas.edu/research-labs-clinical/green-labs/ehs-green-labs-leader-badge) program, which is a self-paced certification program that allows researchers to learn about lab sustainability while they enhance their communication, leadership, critical thinking, and problem-solving skills.

[University of Michigan](https://ocs.umich.edu/programs/) Green Labs program offers certification not only for labs but also for other types of workplaces. They have resources related to waste reduction, energy management, lab reuse programs, and support [initiatives](https://ocs.umich.edu/programs/workplace-initiatives/) including [Green Teams](https://ocs.umich.edu/programs/workplace-initiatives/green-teams/), sustainability training, zero waste events, and sharing promotional materials.

[University of Pittsburgh](https://www.sustainable.pitt.edu/get-involved/employees/pitt-green-office-lab/) Green Labs program Certifies labs based on a point system, providing Certification at four different levels. The self-assessment certification program evaluates labs across chemicals and safety, culture of sustainability, energy consumption and equipment maintenance, innovation actions, lab recycling, purchasing, water conservation, and animal research. The Green Labs program also provides resources for chilling up ULT freezers, chemical redistribution programs, glove recycling, and shut your sash initiatives. This group has also contributed to the creation of a [Student Green Guide](https://www.sustainable.pitt.edu/get-involved/students/student-green-guide/) and [Employee Green Guide](https://www.sustainable.pitt.edu/get-involved/employees/employee-green-guide/), alongside their [Green Ambassadors](https://www.sustainable.pitt.edu/pitt-green-ambassadors/) program. U Pitt also has other sustainability programs of note including [Green Events](https://www.sustainable.pitt.edu/get-involved/pitt-green-events/), [Green Home Office Challenge](https://www.sustainable.pitt.edu/get-involved/employees/home-office-challenge/), [Green Office](http://get-involved/employees/pitt-green-offices-labs/), [Green Residents and Residence Halls,](https://www.sustainable.pitt.edu/get-involved/students/pitt-green-residents-floors/) and [Green Student Organizations](https://www.sustainable.pitt.edu/get-involved/students/student-organizations/).

[University of Washington Seattle](https://sustainability.uw.edu/green-laboratory) launched their Green Labs program in 2013, though it has been on pause for several years, with three Certification levels based on eight categories. Labs are assessed by an interdisciplinary committee and awarded appropriately. This program includes online libraries of resources including topics ranging from chemistry, [communication and education](https://sustainability.uw.edu/green-laboratory/resources#Communication), energy, fieldwork, recycling, travel, and water, to name a few.

[University of Wisconsin Madison](https://sustainability.wisc.edu/certifications/green-labs/) utilizes the (paid-for) My Green Labs Certification program to Certify labs, and have developed resources benefitting not only labs, but the campus. These resources include EHS chemical distribution, recyclopedia, chemical surplus and disposal forms, biological waste disposal, equipment and supplies surplus pickup/dropoff, International Freezer Challenge, green chemistry, glove recycling, pipette tip box recycling, and 12 principles of green chemistry. This program is impressively run entirely by intern teams that provide consultation services and create tools for best practices, and the program utilizes the [UW-Madison Green Fund](https://sustainability.wisc.edu/greenfund/) to provide labs with lots of opportunities to becoming more sustainable, and works toward the [zero waste project](https://zerowaste.sustainability.wisc.edu/) and [net-zero emissions project](https://sustainability.wisc.edu/goals/achieve-net-zero-emissions/) on campus.

[University of Virginia](https://sustainability.virginia.edu/green-labs) Green Labs program includes Green Labs Certification focusing on cold storage, chemicals and reagents, materials and refuse, electronics and appliances, and engagement, that is available as an online form. Lab responses are analyzed and a Green Labs Specialist offers suggestions to make labs more sustainable. Once Certified, labs receive a plaque and other swag, and a feature on the Green Labs website. This program also supports participation in the International Freezer Challenge, Shut the Sash Competition, an energy impact tracker, [smart energy routine](https://sustainability.virginia.edu/sites/g/files/jsddwu1096/files/2024-01/Smart%20Energy%20Routine%20Overview.pdf) initiatives, and Green Labs Working Group. Main focuses of this program include procurement, cold storage, fume hoods, green chemistry, waste and recycling, and other resources, of which they have collected or created various supporting documents, signage, tip sheets, and do’s and don’ts, to name a few.

**(Appendix continued)**

**Appendix Table 1.** List of peer institutions (extended). Links are provided for institutions’ Green Labs program websites or other applicable websites. \* indicates a publicly funded university. If peer institutions have a Green Labs program and a dedicated full-time employee are indicated. R&D funding, endowment, and estimated numbers of research labs are shown.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Institution (with link to Green Labs or Sustainability programs); \* indicates publicly funded university | Green Labs Program (Y/N) | Dedicated Green Labs Full-Time Employee(s) (Y/N, number of employees if available) | [Institutional R&D funding per year](https://ncses.nsf.gov/surveys/higher-education-research-development/2022) (2023) | Endowment | Estimated number of research labs (estimated number of faculty, graduate students, postdocs, and research staff) (numbers of those researchers in labs if available) (PC=personal communication) |
| [California Institute of Technology](https://greenlabs.caltech.edu/) | Y | N | $478,142 | $3.63 B | 300+ (1,200+ faculty, 650 postdocs, 1,400 graduate students500+ research staff) |
| [Carnegie Mellon University](https://guides.library.cmu.edu/c.php?g=935663&p=7236721) | N | N | $449,707 | $3.1 B | 100+ (1,400 faculty, 12,752+ graduate, 193 postdocs, and 500+ research staff) |
| [Cornell University](https://sustainability.weill.cornell.edu/green-labs) | Y | Y (2) | $1,300,357 | $10 B | 100+ (2,300 faculty, 5,300 graduate and 700+ research staff) |
| [Georgia Institute of Technology](https://sustain.gatech.edu/) | N | N | $1,231,485 | $2.97 B | 848 (1,374 faculty, 26,398 graduate, and 2,717 staff) |
| [Johns Hopkins University](https://sustainability.jhu.edu/engage/green-labs/) | Y | Y (1, and 2 graduate student employees) | $3,420,312 | $10.54 B | 900+ (564 faculty, 20,800 graduate, 1600 postdocs, and 3,000+ research staff)(20,000 graduate and staff in labs) (PC) |
| [Massachusetts Institute of Technology](https://ehs.mit.edu/sustainable-labs/) | Y | N (within EHS?) | $989,166 | $23.5 B | 200+ (1,089 faculty, 7,201 graduate, 1,536 postdocs, and 4,275 research staff) |
| [Pennsylvania State University](https://sustainability.psu.edu/programs/sustainable-labs/) \* | Y | Y (6) | $1,019,940 | $4.8 B | 100+ (6,354 faculty, 14,000+ graduate, 525 postdocs, and 2,454 research staff) |
| [Purdue University](https://www.purdue.edu/physicalfacilities/units/cpas/sustainability/index.php) \* | N | N | $754,627 | $3,68 B | 400+ (1,871 faculty, 12,136 graduate, 500 postdocs, and 2000 research staff) |
| [Stanford University](https://sustainable.stanford.edu/operations/buildings-grounds/labs) | Y | N (0.25 employee, 1 student employee) | $1,384,555 | $36.5 B | 2000+ (2,323 faculty, 7,600+ graduate, 2,500+ postdocs, and 3,000+ research staff)(12,000 graduate and staff in labs) (PC) |
| [Texas A&M University – College Station](https://semc.tamu.edu/greens-labs-certification-program/index.html) \* | Y | N (committee) | $1,152,666 | $19.2 B | 500+ (4,100+ faculty, 16,762 graduate, 3,845 research staff) |
| [University of Alabama at Birmingham](https://www.uab.edu/sustainability/greenlab)\* | Y | Y(1.5 and 7.5 student employees) | $713,480 | $1 B | 600 (2,146 faculty, 8,851 graduate, 300 postdocs, 1,000+ research staff) (3300 graduate and staff in labs)(PC) |
| [University of British Columbia](https://sustain.ubc.ca/green-labs) \* | Y | Y |  | $2.8 B (CD) | 300+ (3,800+ faculty, 10,000+ graduate students, 1,000 postdocs, 5,696 research staff) |
| [University of California Berkeley](https://sustainability.berkeley.edu/engage/green-labs-certification) \* | Y | N | $981,035 | $6.8 B | 500+ (1,500+ faculty, 12,621 graduate, 1,088, and 1000+ research staff) |
| [University of California Davis](https://sustainability.ucdavis.edu/green-workplace) \* | Y | N (one member of the sustainability team is involved in GL efforts) | $883,807 | $2.25 B | 200+ (2,500+ faculty, 7,000 graduate, [745 postdocs](https://ucnet.universityofcalifornia.edu/resources/employment-policies-contracts/bargaining-units/postdoctoral-scholars/about/), and 1200+ research staff) |
| [University of California Irvine](https://sustainability.uci.edu/green-lab/) \* | Y | N (GL working group) | $534,947 | $1.3 B | 100+ (1,553 faculty, 8,019 graduate, 451 postdocs, 6,890+ research staff) |
| [University of California Merced](https://sustainability.ucmerced.edu/get-involved/faculty-and-staff/green-lab-program) \* | Y | N (intern) | $48,147 | $84.4 M | 100+ (482 faculty, 775 graduate, 73 postdocs, and 1,359 research staff) |
| [University of California Riverside](https://sustainability.ucr.edu/green-labs-program) \* | Y | N | $199,135 | $259.8 M | 200+ (589 faculty, 3,906 graduate students, 224 postdocs, and 2,000+ research staff) |
| [University of California San Diego](https://sustain.ucsd.edu/involve/green-labs.html) \* | Y | N? | $1,533,357 | $3 B | 300+ (3,804 faculty, 9,872 graduate, 1,211 postdocs, 3,822 research staff) |
| [University California of San Francisco](https://campuslifeserviceshome.ucsf.edu/sustainability/certifications) \* | N | N (1 student employee as needed) | $1,805,950 | $2.5 B | 600+ (3,000+ FT faculty, 3,114 graduate, 1,139 postdocs, 500+ research staff) (4,700 graduate and staff in labs) (PC) |
| [University of California Los Angeles](https://www.sustain.ucla.edu/green-labs/) \* | Y | Y (2? Grant coordinator and zero waste manager) | $1,536,197 | $7.7 B | 800+ (2,960 faculty, 14,007 graduate, 989 postdocs, and 7,941 research staff) |
| [University of Colorado Boulder](https://www.colorado.edu/ecenter/programs/cu-green-labs-program) \* | Y | Y (2 plus 12 student employees) | $611,380 | $2.1 B | 400+ (4,800 faculty (2,000 research faculty), 6,446 graduate, and 900 research staff) (2,000 graduate researchers and staff in labs)(PC) |
| [University of Georgia](https://greenlab.uga.edu/)\* | Y | Y (1 and 2 student employees) | $545,631 | $1.4 B | 250+ (3,000+ faculty, 9,041 graduate, 1,000+ research staff) |
| [University of Illinois at Urbana Champaign](https://sustainability.illinois.edu/green-certifications/certified-green-chapter-program/) \* | N | N | $765,909 | $2.51 B | 150+ (2,708 faculty, 20,500 graduate, 500+ postdocs, 4,500+ research staff) |
| [University of Michigan](https://ocs.umich.edu/programs/) | Y | Y (1, and 1 student employee) | $1,770,708 | $17.9 B | 600+ (7,954 faculty, 18,335 graduate, and 3,800 research staff)(4,000 graduate and staff in labs)(PC) |
| [University of Pittsburgh](https://www.sustainable.pitt.edu/get-involved/employees/pitt-green-office-lab/) | Y | N (1 PT employee) | $1,251,998 | $5.5 B | 2,000 (4,900 faculty, 9,500 graduate, 800 postdocs, and 7,200 research staff) (14,000 graduate and staff in labs)(PC) |
| [University of Southern California](https://dornsife.usc.edu/news/stories/chemists-create-greener-research-labs/) | N | N | $1,039,905 | $8.13 B | 800+ (4,767 FT faculty, 28,500 graduate, 500+ research staff) |
| [University of Texas at Austin](https://ehs.utexas.edu/research-labs-clinical/green-labs) \* | Y | Y (1 under EHS, with 0.2 support, and 1.5 student employees) | $845,896 | $18.8 B | 540+ (3,000 faculty, 12,100 graduate, 700 postdocs, and 1000+ research staff) (4,700 graduate and staff in labs)) (PC) |
| [University of Washington Seattle](https://sustainability.uw.edu/green-laboratory) \* | Y | N | $1,559,708 | $4.9 B | 500+ (4,000 faculty, 16,124 graduate, 1,100 postdocs, and 5,800 research staff) |
| [University of Wisconsin Madison](https://sustainability.wisc.edu/certifications/green-labs/) \* | Y | N (student interns) | $1,523,513 | $3.8 B | 250+ (4,800 faculty, 9,993 graduate, 750+ postdocs, and 1000+ research staff) |
| [University of Virginia](https://sustainability.virginia.edu/green-labs) | Y | Y (1 and 2 PT employees, 2-3 student employees) | $332,993 | $13.6 B | 500+ (6,149+ faculty, 8,700 graduate, 400+ postdocs, and 5,000 research staff)(2,500 graduate and staff in labs)(PC) |