TECHNISCHE UNIVERSITÄT DRESDEN

Green Lab Guide

Improve your lab’s ecological footprint

DO YOUR PART!

Green Lab Guide TU Dresden

Contents

INTRODUCTION

Laboratories are essential for both research and education, serving as hubs of innovation and discovery. In educational settings, laboratories provide students with hands-on experience, allowing them to apply theoretical knowledge to real-world scenarios. For researchers, laboratories are critical for conducting experiments, developing new technologies, and advancing scientific knowledge across disciplines. Additionally, they foster a collaborative environment where students, faculty, and researchers work together.

Laboratories require an abundance of resources. A laboratory consumes approximately ten times more energy and four times more water in comparison to office space[1]. One study revealed that in 2014, laboratories worldwide produced approximately 5.5 million tons of plastic waste[2]. A -80°C freezer uses the same amount of energy as a single-family home. These resource demands significantly affect the environment.

Sustainability and environmental issues becomes more and more relevant when it comes to applying for research funding. In acknowledging the environmental impact of academic research, the German Research Foundation (DFG), for example, has put forth a Sustainability Guide and those applying for grants must submit a sustainability statement as part of the review process.

This guide includes practical guidance on how to work in a more environmentally friendly way in your laboratory and beyond.

The Green Lab Guide provides information, recommendations and checklist for the following key areas:

- Waste Management
- Procurement
- Energy Use
- IT
- Green Chemistry
- Research Methodology and Design
- Information dissemination

Following these recommendations should reduce energy and water consumption without sacrificing research quality or output. As not all labs use the same materials, users of this guide should adopt and adapt the recommendations according to specific circumstances.

The Green Lab Guide is updated on an ongoing basis. We are always on the lookout for further topics and best practice examples. If you would like to add something, please contact umweltschutz@tu-dresden.de.

GREEN LAB CHECKLIST

Waste Management

- ☐ Think about strategies to reduce lab materials.
- ☐ Use reusable materials and minimize single-use plastic.
- ☐ For residual waste, packaging waste, and paper/cardboard use the three-part bins.
- ☐ Collect Pipette tip boxes separately and dispose of as “packaging waste” (“Grüner Punkt”).
- ☐ Separate hazardous waste, biological substances or genetically modified organisms using the TU Dresden color coded labelling and bin system (see Annex “Pick your color!”).
- ☐ Participate in training on waste disposal offered by the TUD’s dangerous goods safety advisor.
- ☐ Conduct regular waste audits to categorize waste and think about strategies how to recycle most of the plastics (see Annex “How to conduct a waste audit”).

Procurement

- ☐ Share or borrow equipment.
- ☐ Optimize orders to avoid overordering items with high energy storage needs but do bundle orders to minimize shipping.
- ☐ Utilize GoeChem or a similar system for tracking and managing chemical inventories to minimize overstocking
- ☐ Implement inventory system to track lab materials.
- ☐ Carry out regular storage inspections to remove expired or unnecessary samples.
- ☐ Select high quality, durable products.
- ☐ Check for Blue Angel, Energy Star, EU Ecolabel or similar certifications before purchasing new equipment.
- ☐ Give preference to suppliers who minimize transport packaging.
- ☐ Utilize smaller-sized lab materials, e. g. petri dishes, if the experiment allows it.
- ☐ Buy large bulk of pipette tips and refill tip boxes..

Equipment and Infrastructure

- ☐ Turn off equipment when not in use.
- ☐ Regularly perform pipette calibration to ensure accurate measurement.
- ☐ Use the booking system to coordinate the use of common equipment and devices in the institute.
- ☐ Use the Dresden Technology Portal to search for specific equipment, complex systems or service offers for your research.

Large Equipment

- ☐ Close fume hood sashes and biosafety cabinets.
- ☐ Use equipment as instructed by the operating manual.
- ☐ Provide regularly scheduled maintenance for all equipment.
- ☐ Autoclave only necessary items and do not run the autoclave half full.

Cold Storage

- ☐ Share a freezer with a neighboring lab.
- ☐ Raise freezer temperature from -80°C to 70°C and from -20°C to -18°C.
- ☐ Use a sample management system to reduce the time spent looking for sample.
- ☐ Store supplies at room temperature if possible.
- ☐ Regularly defrost and clean refrigerators and freezers.
- ☐ Keep freezers full, ice packs or empty boxes can be placed in gaps.

Lights

- ☐ Turn off lights and use daylight or task lights.
- ☐ Remember to turn off lights when leaving.

IT

- ☐ Use devices as long as possible and ask your admin repairing them if possible.
- ☐ Consider the main parameters (processor, memory and runtime) when choosing hardware.
- ☐ Increase code efficiency if programming software.
- ☐ Enable sleep mode or auto-off on all computers and printers.
- ☐ Avoid screen savers. Apply the low light setting on screens.
- ☐ Search the internet using Ecosia or other ecological search engine.
- ☐ Run routine data clean-up to spot redundancy.
- ☐ Provide links rather than attachments in emails.

- ☐ Place files in cloud storage.
- ☐ Archive data to cold storage (in co-operation with the IT Department).

Green Chemistry

- ☐ Substitute hazardous chemicals or toxic substances with safer, less hazardous materials.
- ☐ Focus on developing or using chemicals that decompose into non-toxic substances.
- ☐ Use catalysts to enhance reaction efficiency and reduce waste.
- ☐ Utilize natural enzymes in biochemical processes for enhanced specificity.

Research Quality

- ☐ Implement protocols that minimize reagent use and employ microscale techniques to reduce chemical consumption.
- ☐ Utilize open-access protocol platforms to improve training and boost efficiency of methods.

Information Dissemination

- ☐ Encourage lab members to propose new ideas for sustainability measures.
- ☐ Appoint a sustainability officer to update the lab on TUD’s sustainability initiatives during meetings.
- ☐ Provide regular training on green lab practices.

WASTE MANAGEMENT

Effective waste management minimizes environmental impact, reduces pressure on landfills, promotes the safety of lab personnel, and ensures compliance with regulations. Proper sorting of contaminated and non-contaminated waste, avoidance of single-use plastics, and promoting reuse are key strategies that reduce waste and conserve energy and resources.

Reduce Waste

Common sources of waste in labs include single-use plastics, a high amount of packaging waste and paper use. Minimizing waste creation prevents waste generation rather than managing it post-production. To avoid waste, labs can prioritize glassware and containers over plastic. Give preference to consumables that have minimal plastic. Regular waste audits (see Annex “How to conduct a waste audit”) in laboratories help identify types and quantities of waste generated, highlighting areas for improvement. By categorizing and analyzing waste, labs can uncover trends and opportunities for waste reduction and better management practices.

Keeping inventories up to date prevents over-purchasing and reduces waste by ensuring only necessary materials are bought and used. Update lists regularly (Excel, LabUtils, GOECHEM), utilize digital tracking systems for real-time stock monitoring, and implement a "first-in, first-out" policy to prevent expiration and unnecessary disposal.

At CRTD, a platform has been established for exchanging chemicals lab devices to facilitate resource sharing and optimize lab use.

For equipping office workstations, TU Dresden Directorate 1, Unit 1.2 (Central Purchases) makes available no longer needed office furniture (see: https://tu-dresden.de/tu-dresden/organisation/zentrale-universitaetsverwaltung/dezernat-1-finanzen-und-beschaffung/sachgebiet-1-2-zentrale-beschaffung/Aussonderung?set_language=en.

Non hazardous, hazardous/medical and electronic waste

Waste disposal at TU Dresden follows the “Abfall-ABC” guidelines in which non-hazardous waste is sorted in a three-part waste system separating “organic and residual waste”, “plastics and aluminum packaging” (German “Grüner Punkt”) as well as “paper and cardboard”. Especially Paper is an important raw material for which recycling works well. (Abfall-ABC”: https://tu-dresden.de/intern/arbeitsschutz-gesundheit-umwelt/umweltschutz-und-umweltmanagement/abfallmanagement/abfall-abc)

Safe disposal of hazardous waste such as chemicals, genetically modified organisms, and medical waste is crucial due to the increased expense incurred and risks these materials pose to health and environment. Autoclaving to inactivate microorganisms minimizes the risks associated with hazardous materials. Sterilization occurs through the use of steam, moisture, heat (at least 121°C) and pressure (105 kPa for a minimum of one hour), Compared to incineration, autoclaving reduces air pollution and is more efficient [3]. The use of autoclaving is mandated for specific types of waste.

Color coded labelling helps classify the various types of hazardous waste (see Annex “Pick your color!”). Chemicals should never be dump down the drains. Proper disposal of chemicals requires using labelled containers (for what it contains or had contained). Due to the high costs of disposing of hazardous waste, non-hazardous waste should not be mixed with hazardous.

The Dangerous Goods Safety Adviser of TU Dresden offers individual training and advice (umweltschutz@tu-dresden.de).

It is obligatory to recycle electronic waste as these devices consist of dangerous components such as heavy metals, which can enter the soil and groundwater. At TU Dresden, electronic waste is collected after submitting a request (Disposal of Asset Form). This form aids in determining whether devices are reused or disposed. Disposal is managed by the *Gruppe Umweltschutz* (umweltschutz@tu-dresden.de). Some devices can be refurbished. Cables should therefore remain on the computer, laptop or monitor. Hard disks should be deleted and removed if this is possible without destroying the device. Disposal and refurbishment are carried out in the company. It has certification for the data protection-compliant erasure of data.

PROCUREMENT

Sustainable procurement guides the selection of products and services aligned with environmental goals. When choosing between products, priority is placed on those firms that manufacture using sustainable practices, local firms to reduce carbon emissions resulting from delivery, and products that result in minimal waste or in recyclable materials. For example, pipette tips can be ordered in bulk and then placed in boxes.

Strategic Purchasing

Carefully planned purchasing results in money saved and reduces waste and energy expenditures. Consider gathering several requests from one firm into one order, thereby reducing the monetary and environmental costs of delivery. Items sent with dry ice that are bought and shipped together net considerable savings. Maintain inventories to avoid accidental redundancies. If you notice expired products, consider buying these in lesser quantities. Products with shorter lifespans might cost less initially, but they need to be replaced rapidly. This increases the total costs and generates additional waste.

Certifications

Energy efficiency ratings and labels enable consumers to assess whether a device is environmentally friendly. The EU energy labels for devices give a letter rating of A to G with an A label being the most energy efficient. Although repairing old equipment reduces waste, purchasing new might substantially reduce energy costs.

Germany awards the Blue Angel (Blauer Engel) seal for products and services deemed particularly environmentally friendly. The EU Ecolabel, EU-Ecoflower, is nearly similar.

Safe procurement and storage of chemicals

Chem 2.0, a new project at TU Dresden, seeks to offer a comprehensive software solution for chemical management in 2025 (GoeChem), with a central hazardous chemical’s directory as its center. This system will standardize the university's hazardous material register, guaranteeing legal compliance while also offering a rapid overview of chemical amounts and distributions. The program will automate the creation and updating of safety data sheets, making them more easily available to employees and students. The program aims to enhance the creation of operating instructions, risk assessments, and buying processes by providing a comprehensive understanding of chemicals and their applications. It will also improve chemical storage administration, resource conservation, and tracking of chemical usage and research data through electronic journal connections.

ENERGY USE

In laboratories, ventilation, exhaust systems, and electrical devices consume 3-5 times more energy than in offices. Therefore it is important to reduce energy use and to implement measures increasing energy efficiency. By identifying inefficiencies such as outdated equipment or unnecessary off-hour usage, labs can conserve resources, minimize their environmental footprint, and lower operational expenses.

Lighting

Lighting accounts for 15% of total lab electricity use.[3] This is approximately twice as much as in office space. Use daylight as the primary light source and supplement using electric lighting. "Task lighting" is tailored to most effectively illuminate specific work. It accomplishes this with greater energy efficiency than general overhead lighting. When leaving an area unoccupied, make sure to switch off the lights.

Fume hoods and biosafety cabinets

Fume hoods and biosafety cabinets require substantial energy to function. A single fume hood uses nearly as much energy as 3,5 homes[4]. Fume hoods utilize powerful fans to pull conditioned air in from in front of the hood for release outside. Keep the sash of the hood closed unless performing experiments within the cabinets. Shutting the sash reduces the amount of air volume drawn from the room as well as protecting lab members from chemical exposure and hazardous materials in the hood. That said; do not conserve energy at the expense of safety.

Cold Storage

Ultra-low temperature (ULT) freezers normally operate at either -40°C or -80°C, accounting for the largest expenditure of energy in a lab[5]. These freezers, especially the older models, consume around 25-30 kWh energy a day. An adjustment from -80°C to -70°C cuts electricity by 30%[3]. This adjustment usually does not affect the quality or the viability of biological samples.

To reduce the need for more freezers, periodically assess the materials stored and eliminate any unneeded reagents or samples. However, be aware that a full freezer operates with greater efficiency than one that is almost empty. Maintaining organization in freezers reduces the amount of time that freezer doors remain open.

Ice formation limits freezer space and efficiency. Moreover, a build-up of dust on the exterior coils causes the freezer to work harder to maintain a stable temperature. Regular coil cleaning and freezer defrosting improves energy efficiency while also extending the life of the device.

Other electric equipment

Use of equipment such as ovens, heating blocks, and centrifuges, requires reaching a specific temperature which often can be achieved in 20 to 40 minutes. Maintaining this temperature, however, consumes a significant amount of energy. Do not turn on until ready to use.

By turning devices off when not in use, a researcher can save up to 10 kWh / day [5]. Alternatively, consider using an energy-saving, stand-by mode when the equipment is not in use.

Autoclave Efficiency

The most common, reliable, and cost-effective way to sterilize is through steam or pressure. However, autoclaving is highly energy and water use intensive.[6] Carefully evaluate the need to autoclave a particular item. Run a cycle only when full.

IT

Computer simulations and mathematical models can replace some experiments, thereby, reducing material waste. However, IT use contributes to the CO_2 footprint[7,8]. It was estimated that in 2020, the IT sector accounted for approximately 2-6% of global CO_2 emissions and it was predicted that in 2030, this figure would grow to 20%[9]. Other adverse environmental effects result from the manufacturing and disposing of computer hardware[9].

Hardware Choice

In choosing hardware, including processor, memory capacity, and task runtime consider the needs of the work to be performed on it. The processor and memory available can be modified on most high-performance computing (HPC) platforms.

Energy requirements are largely dependent on memory availability rather than memory utilization[9]. Parallelization or switching from central processing units (CPUs) to graphics processing units (GPUs) can enhance processor efficiency to minimize runtime, thereby, decreasing energy use.

Buy Refurbished

Refurbished products are pre-owned items that have been repaired, tested, and certified to function like new which are offered at a substantially reduced price. Choosing refurbished electronics directly reduces electronic waste. Additionally, it conserves the energy and raw materials that would have gone into producing a new device. Platforms to buy refurbished electronics include:

- refurbed: www.refurbed.de
- AfB Online shop: www.afbshop.de
- Back Market: www.backmarket.de

Settings of PC and Printer

Sleep mode and power management settings are common features for computers and printers. A sleep setting kicks in when a device sits idle for a determined period. The amount of energy drawn while sleeping is lower than while idling. The small surge of power needed when the computer awakes from sleep mode is more than compensated for by the net gain in not sitting idle.

Even turned off, some gadgets continue to draw a small amount of power. The best way to avoid this is to connect them to a smart power strip, turn off the strip and thus cut off all access to power.

Software Choice

Assuring that you are utilizing the most energy efficient and optimized software for the task is a simple way to reduce the environmental impact of your research. Optimized programs are lower in size, use less memory, and require less execution time[11]. However, improved software efficiency does not always lead to a reduction in computing time and can result in the need for hardware replacement. For more information, please see the "Guide to environmentally friendly public procurement of software" from Umweltbundesamt (https://www.umweltbundesamt.de/sites/default/files/medien/11850/publikationen/leitfaden_beschaffung_software_barrierefrei_0.pdf).

Data storage

Preserving data correctly minimize energy use and prevents experiment duplication. Moreover, the DFG and the TUD require research to be stored for a minimum of ten years. Whether you want to digitally save, back up, or archive your data, the TU Dresden Center for Information Services and High-Performance Computing (ZIH) offers network drives or storage services as well as central data storage to all TU Dresden members. Limitations in capacity and redundant systems are provided based on the user's security and availability needs. Learn more here: https://tu-dresden.de/zih/dienste/service-katalog/arbeitsumgebung/datenspeicher .

GREEN CHEMISTRY

Green Chemistry is an innovative method to create chemical products and processes that minimize or eliminate the creation and use of harmful compounds. It aims to increase the safety for those using the materials as well as ecosystems. Green chemistry can result in waste reduction and improved experimental efficiency.

Sustainable Chemical Design

Sustainable Chemical Design focuses on creating chemical products and processes that have a low environmental effect by using renewable resources and increasing energy efficiency. It strives to develop solutions that are both economically and ecologically sustainable throughout their existence. For example, solvents generated from sustainable resources, such as plant-based solvents like bioethanol, ethyl lactate, or Cyrene™, can substitute for petrochemical-derived compounds. For more information, explore:

https://www.sigmaaldrich.com/IN/en/campaigns/sustainable-chemistry?srsltid=AfmBOors4rgk4RThEsSgxk1wDM8tZiFGcxYIRG6M9TR7B51Smr_kJ5Zq

Safer Chemicals and Processes

Safer Chemicals and Processes seek to replace hazardous compounds with safer alternatives, lowering the risk to human health and the environment. Cleaning solutions without hazardous chemicals such as ammonia or chlorine are less likely to cause health problems. The development of lead-free soldering materials for electronics, avoids the toxicity and health hazards associated with lead exposure.

Minimize hazardous waste

Reducing hazardous waste in laboratories is also critical for safety and environmental protection. Substitute less hazardous materials where possible, use minimal quantities, and store chemicals properly. Implementing miniaturized techniques can drastically reduce waste generation, cutting disposal costs, improving lab safety and decreasing the need for extensive disposal procedures and autoclaving, thereby lowering associated energy consumption and costs.

Catalysis vs. Stoichiometric Reactions

Prioritize catalytic processes, which employ catalysts to boost reaction efficiency and reduce waste to stoichiometric reactions, which use precise proportions of reactants and create more waste. Catalytic processes employing natural enzymes are used in biochemical processes to provide great specificity and efficiency while generating less waste than standard chemical reactions.

RESEARCH METHODOLOGY AND DESIGN

The manner in which we conduct research, manage our data, and apply methods influences the efficient use of resources. A research group can include this in their research approach and develop ideas for optimizing methods in this area.

Open-Access Data and Protocol Platforms

Published, trusted data potentially can be built upon rather than reproduced or replicated. Learning a technique not established in the lab or optimizing a new kit can result in first runs that waste materials and time and do not lead to data generation. Websites such as Protocols.io or GitHub offer researchers a place to share fine-tuned, peer-reviewed methods and, thus, prevent some waste.

Miniaturization

When performing chemical reactions or biological assays, scaling smaller for pilot studies can reduce the quantity of materials used. For instance, low-volume PCR protocols reduce the volume of DNA samples and reagents required. Algorithms can guide minimum sample size needed for statistical significance. The DFG asks that researchers consider fitting the scale of the experiment or field trial to the scope required to answer the question or substituting a simulation wholly or in part.

INFORMATION DISSEMINATION

It is important to stay informed regarding sustainability measures. To this end, each lab should appoint a Sustainability Officer to stay abreast of developments, particularly those stemming from the TUD, and report these to their team for implementation.

TUD is dedicated to addressing global environmental challenges through sustainable practices. The university aims to be a flagship for efficient resource use, environmental respect and responsible action.

Strategy: TUD has outlined a comprehensive Sustainability Strategy focusing on six key areas: governance, campus operations, research, teaching, digitalization, and dialogue. The strategy aims to achieve climate neutrality by 2035, minimize resource consumption, and foster sustainable development.

Research and Teaching: The University is committed to conducting research that addresses environmental and climate issues and supports sustainable societal change. TUD integrates sustainability into its curriculum to equip students with the knowledge and skills for responsible action.

Campus Operations: TUD is working towards a green campus by implementing energy-saving measures, reducing waste, and promoting sustainable transportation. The university is also focused on constructing and renovating buildings according to sustainability standards.

Challenges and Opportunities: Laboratories are significant resource consumers, and TUD is addressing this through initiatives like the Green Lab Guide. The university recognizes the importance of digitalization but aims to ensure it is ecologically sustainable and fair.

Collaboration and Engagement: TUD emphasizes collaboration with students, staff, and the community to achieve sustainability goals. The university is actively involved in public discourse on sustainable development and seeks to influence policymakers.

There are many things you can do to improve sustainability in your everyday work and study life with minimal effort. Here, you will find tips on saving energy, how to travel in a sustainable way, how to borrow a cargo bike, how to purchase in an eco-friendly fashion, and how to plan events and meeting sustainable.

See: https://tu-dresden.de/tu-dresden/nachhaltigkeit/mitmachen/nachhaltigkeit-im-hochschulalltag/

REFERENCES

1. About. My Green Lab https://www.mygreenlab.org/about.html.
2. Urbina, M. A., Watts, A. J. R. & Reardon, E. E. Labs should cut plastic waste too. Nature 528, 479–479 (2015).
3. Top 9 Actions To Take in the Lab to Improve Energy Efficiency. My Green Lab http://www.mygreenlab.org/2/post/2021/01/top-9-actions-to-take-in-the-lab-to-improve-energy-efficiency.html.
4. Wesolowski, D. et al. The use of feedback in lab energy conservation: fume hoods at MIT. International Journal of Sustainability in Higher Education 11, 217–235 (2010).
5. Ultra-Low Temperature Freezers: Opening the Door to Energy Savings in Laboratories | ETCC. https://www.etcc-ca.com/reports/ultra-low-temperature-freezers-opening-door-energy-savings-laboratories.
6. Autoclave Energy Consumption & Autoclave Water Requirements. Priorclave - International (en) https://www.priorclave.com/en/why-priorclave/autoclave-energy-water-consumption/.
7. Dry Lab - SELs Network. https://sels-network.org/index.php/sels-resources/dry-lab/ (2022).
8. Dry – Green Labs – NL. https://www.greenlabs-nl.eu/dry/.
9. Lannelongue, L., Grealey, J., Bateman, A. & Inouye, M. Ten simple rules to make your computing more environmentally sustainable. PLOS Computational Biology 17, e1009324 (2021).

11. Gotarane, P. & Pundkar, S. Smart Coding using New Code Optimization Techniques in Java to Reduce Runtime Overhead of Java Compiler. International Journal of Computer Applications 125, 11–16 (2015)

ANNEX 1: PICK YOUR COLOUR!

The following Color Coded Labeling System shows how to classify hazardous waste at TU Dresden (based on a presentation of TUD's Gruppe Umweltschutz; umweltschutz@tu-dresden.de).

Gelb / Orange **Yellow / Orange**	**feste Abfälle, Verpackungen** **Solid waste, packaging**
	kontaminierter Glasabfall jeglicher Art z.B. entleerte Glasgebinde mit gefährlichen Anhaftungen Contaminated glass waste of any kind e.g., Empty glass containers with dangerous buildup
	Verpackungen die Rückstände gefährlicher Stoffe enthalten oder durch gefährliche Stoffe verunreinigt sind z. B. entleerte Fässer und Kanister aus Kunststoff mit gefährlichen Anhaftungen entleerte Fässer und Kanister aus Metall mit gefährlichen Anhaftungen Packaging containing the residues of hazardous substances or contaminated by hazardous substances e.g., emptied barrels and canisters made of plastic with dangerous buildup emptied barrels and metal canisters with dangerous buildup
	Aufsaug- und Filtermaterial Chemikalien behaftete verunreinigte Handschuhe, Pipettenspitzen, Objektträger, Schläuche, Kunststoffteile, Putzlappen, Papiertücher, Chemikalienbinder, Filtrationshilfsmittel bzw. Aufsaugmassen auf anorganischer und organischer Basis wie z. B. Aktivkohle, Silicagel, Kieselgel, Kieselgur und ethidiumbromidhaltige Gele Absorbent and filter material contaminated gloves, pipette tips, slides, hoses, plastic parts, cleaning cloths, paper towels, chemical binders, filtration aids or inorganic or organic based absorbent compositions such as activated carbon, silica gel, diatomaceous earth and gel containing ethidium bromide

<table>
<tr><th>Grün
Green</th><th>Lösungsmittel
Solvent</th></tr>
<tr><td>
</td><td>Organische halogenfreie Lösungsmittel, wie Ethanol, Xylol, Toluol und deren Gemische sowie halogenfreie Lösungsmittelgemische mit niedrigem Wassergehalt < 10%.
Abfall darf keine radioaktive Belastung aufweisen.
Der Annahmegrenzwert des Entsorgers liegt bei 300 nSv/h (!).

Organic halogen-free solvents such as ethanol, methanol, xylene, toluene and mixtures thereof and halogen-free solvent mixtures with a low water content <10%.
Waste must not be radioactive.
The acceptance limit of the disposal company is 300 nSv / h (!).</td></tr>
<tr><td>
</td><td>Organische halogenhaltige Lösungsmittel und halogenhaltige Lösungsmittel wie Chloroform, Dichlormethan, Methanol, Phenol, Tetrachlorkohlenstoff und deren Gemische.
Abfall darf keine radioaktive Belastung aufweisen.
Der Annahmegrenzwert des Entsorgers liegt bei 300 nSv/h (!).

Organic halogenated solvents and halogen-containing solvents such as chloroform, dichloromethane, carbon methanol; phenol, tetrachloride and mixtures thereof.
Waste must not be radioactive.
The acceptance limit of the disposal company is 300 nSv / h (!)</td></tr>
</table>

<table>
<tr><th>Violett
Purple</th><th>Lacke und Farben; Klebstoffe
Varnishes and paints; adhesives</th></tr>
<tr><td>
</td><td>Farb und Lackabfälle, die organische Lösungsmittel oder andere gefährliche Stoffe enthalten, nicht ausgehärtete Altfarben, Altlacke und Klebstoffe sind gefährlicher Abfall Vollständig ausgehärtete Farb- und Lackreste bitte in den Restabfall

Paint and varnish waste containing organic solvents or other hazardous substances, Uncured old paints, old coatings and adhesives are dangerous waste, Completely cured paint and varnish residues to be put in the residual waste</td></tr>
<tr><td>
</td><td>Klebstoff- und Dichtmassenabfälle, die organische Lösungsmittel oder andere gefährliche Stoffe enthalten

Adhesive and sealant waste containing organic solvents or other dangerous substances,</td></tr>
</table>

Braun **Brown**	Organische / anorganische Stoffe (fest und flüssig) Organic / inorganic substances (solid or liquid)
	gebrauchte organische Chemikalien, die aus gefährlichen Stoffen bestehen oder solche enthalten alle **festen organischen Laborchemikalien** im Originalgebinde, die nicht mehr benötigt werden used **solid organic chemicals** consisting of or containing hazardous substances all solid organic laboratory chemicals in their original containers that are no longer needed
	gebrauchte organische Chemikalien, die aus gefährlichen Stoffen bestehen oder solche enthalten alle **flüssigen organischen Laborchemikalien** im Originalgebinde, die nicht mehr benötigt werden used **liquid organic chemicals** consisting of or containing hazardous substances all liquid organic laboratory chemicals in their original containers that are no longer needed
	gebrauchte anorganische Chemikalien, die aus gefährlichen Stoffen bestehen oder solche enthalten (Natrimhydroxid-, Kliumhydroxidlösung) alle **festen anorganischen Laborchemikalien** im Originalgebinde, die nicht mehr benötigt werden used inorganic chemicals consisting of or containing hazardous substances (sodium hydroxide, potassium hydroxide solution) all **solid inorganic laboratory chemicals** in their original containers that are no longer needed
	gebrauchte anorganische Chemikalien, die aus gefährlichen Stoffen bestehen oder solche enthalten (Natrimhydroxid-, Kliumhydroxidlösung) alle **flüssigen anorganischen Laborchemikalien** im Originalgebinde, die nicht mehr benötigt werden used inorganic chemicals consisting of or containing hazardous substances (sodium hydroxide, potassium hydroxide solution) all **liquid inorganic laboratory chemicals** in their original containers that are no longer needed

Rosa **Pink**	**Organische / anorganische Säuren** **Organic / inorganic acids**
	wässrige organische Lösungen Sauer z. B. mit Wasser (H_2O) > 10 % vermischte Kohlensäure: H_2CO_3 (Lebensmittelindustrie, Technik, Atmosphäre), Essigsäure: CH_3COOH (Lebensmittelindustrie) aqueous organic solutions acid e.g., mixed with water (H_2O)> 10% carbonic acid: H_2CO_3 (food industry, technology, atmosphere) acetic acid: CH_3COOH (food industry)
	giftige anorganische Lösungen sauer, z. B. mit Wasser(H_2O) > 10 % vermischte Schwefelsäure: H_2SO_4 (industrielle Verwendung, Saurer Regen), Salzsäure: HCl (industrielle Verwendung), Kieselsäure: H_4SiO_4 Phosphorsäure: H_3PO_4 (Lebensmittelindustrie, unter anderem Cola, DNA), Flusssäure: HF (Computerchipherstellung) Salpetersäure: HNO_3 (industrielle Verwendung) toxic aqueous inorganic corrosive e. g. mixed with water (H_2O)> 10% Sulfuric acid: H_2SO_4 (industrial use, acid rain) hydrochloric acid: HCl (industrial use) silica: H_4SiO_4, $_p$hosphoric acid: H_3PO_4 (food industry, including cola, DNA), hydrofluoric acid: HF (computer chip production) nitric acid: HNO_3 (industrial use)

Rot **Red**	**andere Säuren und Pestizide** **other acids and pesticides**
	Pestizide Pflanzenschutzmittel (PSM), Produkte zur Bekämpfung von Schädlingen (wie Ratten, Insekten, Pilze, Mikroben), also beispielsweise Rattengifte oder Holzschutzmittel Pesticides plant protection products (PPP), products for controlling pests (such as rats, insects, fungi, microbes), such as rat poisons or wood preservatives
	andere Säuren (Säuren und Säurengemische ohne Wasseranteil ph 1-5) other acids (acids and acid mixtures without water content ph 1-5)

<table>
<tr><th>Dunkelrot
Dark red</th><th>Quecksilberverbindungen
Mercury compounds</th></tr>
<tr><td>
</td><td>Quecksilberverbindung, flüssig (Thermometer, Versuchsinstrumente mit Quecksilber)

mercury compound, liquid (thermometers, experimental instruments with mercury)</td></tr>
</table>

<table>
<tr><th>Blau
Blue</th><th>basische Lösungen, andere Basen
alkaline solutions, other alkalis</th></tr>
<tr><td>
</td><td>wässrige organische Lösungen basisch
z. B. ($CaCO_3$, CaO und $Ca(OH)_2$), Natron, Soda, Pottasche und Ammoniak)
verfallene Desinfektionsmittelkonzentrate (lösungsmittelhaltig)

aqueous organic solutions basic
e.g. ($CaCO_3$, CaO und $Ca(OH)_2$), natron, soda, potash and ammonia)
diluted disinfectant concentrates (containing solvents)</td></tr>
<tr><td>
</td><td>andere Basen
(Laugen und Laugengemische ohne Wasseranteil pH-Wert 8-14)

other bases
(lyes and mixtures of lye without water content pH-value 8 -14)</td></tr>
</table>

Grau **grey**	**spitze und scharfe Gegenstände, Schmiermittel** **Pointed and sharp objects, emulsions**
	spitze oder scharfe Gegenstände mit Ausnahme derjenigen, die unter AVV 18 01 03 fallen Abfälle wie Kanülen, Skalpelle und Gegenstände mit ähnlichem Risiko für Schnitt- oder Stichverletzungen pointed or sharp objects other than those mentioned in AVV 18 01 03 fall waste such as cannulas, scalpels and items with similar risk of cuts or puncture wounds
	Bearbeitungsemulsion, halogenfrei Kühlschmieremulsion, Kühlschmiermittel oder Kühlschmierstoffe (KSS), Bohrmilch oder Schleifmilch, processing emulsion, halogen-free cooling lubricants, drilling milk or grinding milk

Blaugrau, Dunkelgrau **blue grey, dark grey**	**feste umweltgefährdende Stoffe** **solid environmentally hazardous waste**
	Abfälle von Chemikalien für die Landwirtschaft, die gefährliche Stoffe enthalten (z. B. ausländische Bodenproben und Pflanzenschutzmittel, Klärschlammproben etc.) waste from agricultural chemicals containing dangerous substances (e.g., foreign soil samples and plant protection products, sewage sludge samples etc.)
	Asbesthaltiger Baustoffabfall building material waste containing asbestos

Weiß **White**	**ADR[1]-frei** **ADR-free**
	Frostschutzmittel Antifreeze
	gefährlicher Elektroschrott (z. B. Kühlgeräte, Computer, Bildschirme) hazardous electrical scrap (e. g. fridges, freezers, monitors, computers)

Kennzeichnungssystem / Labelling System

- **UN-Nummer:** Eine eindeutige Kennzeichnung, die von den Vereinten Nationen für gefährliche Stoffe oder Gegenstände während des Transports vergeben wird.
- **UN number:** A unique identifier assigned by the United Nations for hazardous substances or articles during transport.

- **H-Sätze**: Standardisierte Gefahrenhinweise gemäß EU-GHS-Verordnung für Stoffe und Gemische.
- **HS**: Standardized hazard statements according to the EU GHS Regulation for substances and mixtures.

- **AVV** (Abfallverzeichnis): Klassifizierung und Regelung der Entsorgung von Abfällen in Deutschland.
- **AVV** (Waste Catalogue): Classification and regulation of waste disposal in Germany.

[1] Übereinkommen über die internationale Beförderung gefährlicher Güter auf der Straße / Agreement concerning the International Carriage of Dangerous Goods by Road (ADR)

ANNEX 2 - HOW TO CONDUCT A WASTE AUDIT

A waste audit in a laboratory is essential for optimizing waste management, ensuring regulatory compliance, and promoting sustainability. By identifying waste types and inefficiencies, labs can reduce waste, cut disposal costs, and improve safety. Waste audits also support environmental goals through recycling and resource conservation, while enhancing public image by demonstrating commitment to responsible practices. In short, waste audits are vital for labs aiming to improve operations, save costs, and uphold environmental and safety standards.

Procedure	**Details**
Step 1: Preparation	
Build a team	Assemble a team of students or laboratory staff who will participate in the audit. Depending on the size of the laboratory and the scope of the audit, you can form one or more teams.
Choose the audit date	Pick an appropriate date for conducting the waste audit, ensuring it aligns with the laboratory's regular operations. Avoid scheduling the audit on days when special experiments or events are planned in the laboratory.
Equipment and supplies	Ensure you have all the required equipment and materials ready, including: Transparent garbage bags or bins for segregating waste Labels and pens for marking waste containers Personal protective equipment like lab coats, gloves, and, if needed, safety goggles Lists detailing the different types of waste streams to be assessed and data collection forms.
Step 2: Identification and Segregation	
Identify waste stream	Survey the laboratory to identify all types of waste generated, including hazardous chemicals, biological materials, packaging, glassware, plastic, paper and non-hazardous waste.
Wase segregation and bin provision	Ensure clear garbage bags or containers are strategically placed in relevant areas of the lab to collect different waste streams. These bins should be labeled clearly to indicate which types of waste belong in each container, promoting easy and accurate disposal.
Step 3: Quantification	
Collection of waste	During the waste audit, gather the waste into the designated containers, ensuring accurate sorting of materials into the correct bins.
Record data	Utilize a spreadsheet or recording system to document the data obtained for each waste stream. Record the date, type of waste, location, and other details in checklist for accurate documentation and remarks.
Step 4: Analysis	
Analyze waste composition	Review the data collected to identify the types and proportions of waste generated, focusing on opportunities for waste reduction and recycling.
Assess current practices	Evaluate existing waste management practices, including segregation, storage, handling, and disposal methods, to identify

	areas for improvement. Additionally, review procurement strategies to ensure that materials and chemicals are sourced in a way that minimizes waste production, such as purchasing in appropriate quantities, choosing products with less packaging, and selecting suppliers who offer sustainable alternatives.
Step 5: Opportunities for Improvement	
Identify opportunities	Based on the findings of the waste audit, identify specific opportunities for waste reduction, recycling, reuse, procurement and process optimization.
Communicating the results	Inform laboratory staff about the results of the waste audit. Highlight areas where improvements are needed and suggest measures for waste reduction and separation.
Develop action plan	Formulate an action plan outlining steps, responsibilities, and timelines for implementing recommended improvements, prioritizing initiatives based on feasibility and impact.
Step 6: Implementation	
Implement changes	Execute the action plan, deploying resources and engaging stakeholders to implement waste reduction and recycling initiatives identified during the audit.
Monitor progress	Track progress towards waste reduction goals, regularly reviewing performance metrics and adjusting strategies as needed to achieve desired outcomes.
Step 7: Evaluation	
Evaluate effectiveness	Periodically assess the effectiveness of implemented initiatives in reducing waste generation, improving waste management practices, and achieving sustainability objectives. Choose suppliers who provide eco-friendly alternatives, such as bio-based products that are sustainable and better for the environment.
Continuously improve	Iterate the waste audit process, incorporating lessons learned and feedback to continually improve waste management practices and promote a culture of sustainability in the laboratory.

ANNEX 3 – HOW TO CONDUCT AN ENERGY AUDIT

Conducting an energy audit in a laboratory is essential for optimizing energy efficiency, reducing costs, enhancing safety, and promoting sustainability. Identifying inefficiencies such as outdated equipment or unnecessary off-hour usage, labs can conserve resources, minimize their environmental footprint, and lower operational expenses. Additionally, addressing risks from inefficient systems ensures staff safety. Prioritizing energy management not only streamlines operations but also strengthens a lab's reputation as an eco-conscious and responsible organization.

Procedure	**Details**
Step 1: Preparation	
Build a team	Assemble a team of students or laboratory staff who will participate in the audit. Depending on the size of the laboratory and the scope of the audit, you can form one or more teams
Plan and organize the audit date	Define the scope of the audit, e.g., specific lab areas or equipment types to focus effort effectively. Pick an appropriate date for conducting the energy audit, ensuring it aligns with the laboratory's regular operations. Avoid scheduling the audit on days when special experiments or events are planned in the laboratory
Equipment and supplies	Ensure you have all the required equipment and materials ready, including: • Power consumption meter • (optional) Smartphone to connect the measuring device with the app to record the results. Make sure it can be left in the lab all the time • Personal protective equipment like lab coats, gloves, and if needed, safety goggles • Lists detailing the different types of equipment to be assessed and data collection forms
Step 2: Audit Phase	
Primary data collection	Document how and when the equipment is typically used, paying special attention to peak usage times and any equipment left running during off-hours. You can make a list for the lab members to check out whenever they are using the measured device(s).
Conduct detailed trials for selected energy guzzlers	Trials or experiments by monitoring the power consumption (e.g., kWh, Watt, CO_2. emission) of various equipment using the power consumption over a specific period of time, typically duration required for a standard experiment in the lab. Experiments are conducted under 3 different conditions; when the device is turned off, on stand-by, and in-use.

	To measure the energy consumption, you can borrow the energy meter from TUD's Gruppe Umweltschutz (umweltschutz@tu-dresden.de)
Step 3: Analyses	
Analyze the energy use	Review the collected data to identify the types and amounts of energy consumed, focusing on opportunities for reducing usage and improving efficiency. This may include evaluate the equipment efficiency by looking up the energy efficiency ratings (if available) for each piece of equipment and compare them to modern standards.
Assess current practice	Evaluate existing energy management procedures, including operation and maintenance of systems, usage patterns, and efficiency measures. Based on the data collected, determine which equipment is consuming more energy than necessary. This could be due to inefficiencies, poor maintenance, or outdated technology.
Review procurement strategies (optional)	Ensure that equipment and materials are sourced in a way that supports energy efficiency, such as purchasing energy-efficient products, choosing those with lower energy consumption, and selecting suppliers who prioritize sustainable practices. Compare lab equipment energy use with industry standards or similar labs to understand where improvements can be made.
Step 4: Opportunities and Improvement	
Identify opportunities	Based on the findings of the energy audit, pinpoint specific opportunities for reducing energy consumption, improving efficiency, and optimizing processes. Consider areas such as equipment upgrades, energy-saving practices, and more efficient operation schedules.
Communicating the results	Share the results of the energy audit with relevant staff. Emphasize areas where energy use can be improved and suggest actionable measures for enhancing efficiency and reducing consumption.
Develop action plan	Create an action plan that outlines the steps, responsibilities, and timelines for implementing the recommended improvements. Prioritize initiatives based on their feasibility and potential impact to ensure effective and efficient energy management.
Step 5: Implementation	
Implement changes	Execute the action plan by allocating resources and involving key stakeholders to implement the energy-saving measures identified during the audit. Ensure that all planned improvements are put into practice effectively.
Monitor progress	Track progress toward energy efficiency goals by regularly reviewing performance metrics. Adjust strategies as needed to

	stay on course and achieve the desired outcomes, making refinements to enhance results over time.
Step 6: Evaluation	
Evaluate effectiveness	Periodically assess the effectiveness of implemented energy-saving measures in reducing consumption, improving efficiency, and meeting sustainability objectives. Select equipment and suppliers that offer energy-efficient and eco-friendly alternatives to further enhance environmental benefits.
Continuously improve	Iterate the energy audit process by incorporating lessons learned and feedback. Continuously improve energy management practices and foster a culture of sustainability within the laboratory, ensuring ongoing optimization and adaptation to new technologies and methods.